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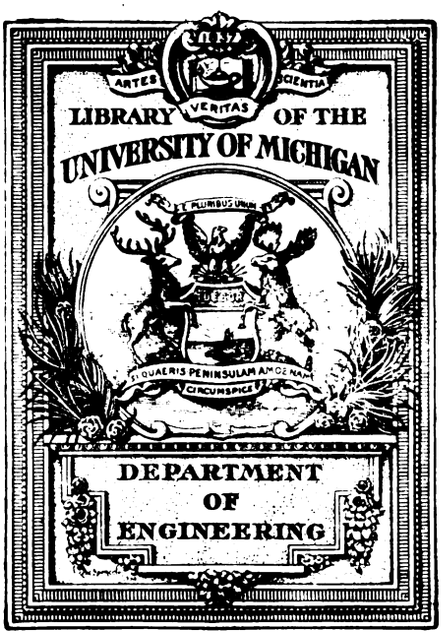
CHICAGO MAIN DRAINAGE CHANNEL.

C. S. HILL.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THE CHICAGO

MAIN DRAINAGE CHANNEL.

5-9312

A Description of the Machinery Used and Methods of Work Adopted in Excavating the 28-Mile Drainage Canal from Chicago to Lockport, Ill.

BY

CHARLES SHATTUCK HILL, C. E.,

Associate Editor, Engineering News.

Reprinted from Engineering News (Vols. XXXIII. and XXXIV.), with much additional matter.

With 100 Illustrations and an Index.

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PREFACE.

The drainage canal which the city of Chicago is constructing to dilute the sewage-laden waters of the Chicago River and carry them west to the Mississippi River far from the city's source of water supply, ranks as one of the greatest works of constructive engineering in the world. This volume gives a brief history of the causes which led to the beginning of this canal, and illustrates and describes in considerable detail the machinery used and methods of work adopted in its excavation. In the work some 40,000,000 cu. yds. of earth and rock were required to be excavated. This, with the policy of letting the excavation in short sections to many contractors, and the variableness of the materials to be excavated, operated to develop a great variety of different devices for doing the work. It is probably not too much to say that nowhere at any time in the history of the world have so many novel and different machines for excavating and removing earth and rock been in operation in so small a territory. To the American engineer who has in mind the methods adopted on the great European canals, it should be also a matter of pride to note that, with the experience of the Manchester, Baltic, and Suez canal works before the builders of this canal, none of the characteristic English, German or French methods of work were adopted. With practically no experience in canal excavation on so great a scale, engineers and contractors have united in developing, for carrying on such work, methods and apparatus which will challenge the competition of the whole world for economy and efficiency.

In describing the different systems of work every effort has been made to secure reliable figures of efficiency and cost. In many instances these figures are less complete than could be wished, owing to the reluctance of the contractors to make public the details of their private business, but nothing is risked in saying that nowhere outside of the official records of the canal engineers are there so complete figures of the work as a whole. In all cases except where specifically stated, the figures given are taken from the actual records kept by the contractors and engineers. It is believed that the especial attention which has been paid to this feature will make the book of especial value in making estimates.

The book is a reprint of the series of articles which has appeared in Engineering News during the past year, but with numerous additions and revisions to bring the work as closely up to date as practicable. It is believed that the articles will be appreciated in their present compact form even by those who have read them from week to week in Engineering News, while for those who have not the files of that journal at hand, this is practically the only form in which the complete series of articles can be secured.

In conclusion the publishers wish to acknowledge their indebtedness to the contractors and engineers of the Sanitary District of Chicago who have aided in many ways to make the descriptions and illustrations of different devices complete and of value, and have worked often to their personal inconvenience to supply figures of the efficiency and cost of different systems of work.

Chicago, February, 1896. CHAS. S. HILL.

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ERRATA.

The following errata aside from typographical errors and obvious misprints, have been called to the writer's attention.

Relative to cantilever crane work the Brown Hoisting & Conveying Machine Co. write as follows:

On page 78, where you give the number of skips as from 25 to 30, it should read "25 to 40." On page 85 there is evidently a misprint in the second line from the bottom of Table IV. In reference to the remark beginning in the 16th line on page 86 we wish to say that the cantilevers were placed to suit the convenience of the contractors in reference to the position of their compressors, drills and channeling machines at the time the cantilevers were furnished. This caused considerable loss of time in moving back and forth over long distances, which would have been obviated if they could have been placed in the more favorable positions that were first contemplated, that is, so that the cantilevers could progress in one direction, contrary to the down-grade of the canal, so that the water would flow away from the working faces and the divisions allotted to each cantilever would join each other. The divisions then would have been finished at about the same time. As it was, two cantilevers finished work ten months before the contracted time and the remaining six finished six months ahead of the contracted time.

In describing the Vivian dredge on page 64 it is stated that it swung on a rear spud as a pivot. Statement is made by a gentlemen on the work that this is incorrect, and that the swinging was done by means of guy lines to the opposite banks.

CHAPTER I.

HISTORY OF THE INAUGURATION OF THE WORK.

HE first effort to provide the city of Chicago with a sewerage system was made in 1855, when the Illinois Legislature passed a bill creating a Board of Sewerage Commissioners to be appointed by the City Councils. The late E. S. Chesbrough, M. Am. Soc. C. E., the father of sanitary engineering in this country, was made the chief engineer of the first commission appointed by the authority of this act, and soon after his appointment he set energetically at work on the problem which he was called upon to solve. The full difficulties of the problem presented at that time can hardly be realized at the present day. The systematic sewerage of cities, as that term is now understood, was then unknown in this country. Cesspools were regarded as the proper receptacles for house drainage and sewers simply as channels for carrying off the surface water.* Not only was the engineer able to profit little by the experience of other cities, but the local conditions were unfavorable. The area which it was proposed to drain (roughly what is now comprised between Chicago Ave. and Twelfth St., on the north and south, and Lake Michigan and Halstead St., on the east and west) was only 12 or 14 ft. above the lake at the higher points and from this elevation the surface descended irregularly to a height of only 3 or 4 ft. above the lake, in the vicinity of the Chicago River. This necessitated raising the grades of the streets and filling in large areas of low land, in order to keep the sewers under ground.

The first step taken by the Board of Sewerage Commissioners was to call for plans and suggestions. There were 39 plans submitted in answer to this request, and although none of them were adopted, they furnished many hints and suggestions to the Board. In the last part of December, 1855, Mr. Chesbrough made his first report,** outlining a complete sewerage system. Briefly stated, the plan proposed was to discharge all of the sewage into the Chicago River through mains placed in alternate streets running to the river, or about 800 ft. apart, into which the laterals from the side streets were to empty. The main sewers were from 3 ft. to 6 ft. in diameter and the laterals 2 ft. in diameter, and all were to be constructed of brick. For the purpose of flushing the sewers, it was proposed to lay lines of water pipe, which were to be supplied with water pumped from the lake or the Illinois & Michigan Canal, according to their location. The engineer also realized that the Chicago River could hardly be kept fresh with all this sewage flowing into it, unless some means of flushing it could be provided. Accordingly, the plans provided for a canal 20 ft. wide and 6 ft. deep, with timber sides, along 16th St. from the lake to the river, through which water could be forced into the upper part of the South Branch.

As indicating the thoroughness with which Mr. Chesbrough had studied the problem, it may be noted that he at that time considered that ultimately it would be necessary to construct an outlet to the southwest for carrying away the city's sewage and for that reason discharged none of his sewers directly into the lake. He, however, realized that such an outlet was not warranted at that time, and provided for the discharge of the sewers into the South Branch, which could at any future time be connected with an outlet to the southwest, but would temporarily carry the sewage into the lake. Another point worthy of note is the fact that none of the sewage was to be discharged into the North Branch of the river as long as the population could be accommodated by the sewers entering the South Branch. In other words, the engineer realized that some means of flushing the North Branch would have to be provided as soon as any great quantity of sewage began to flow into it. Such provision had been made for the South Branch by means of the 16th St. canal, and

* In England up to the year 1815 it was penal to discharge sewage or offensive matters into the sewers. Afterwards it became permissive, and in the year 1847 the first act was obtained making it compulsory to drain houses by sewers.

** The full text of this report was published in Engineering News for the months of April, May and June, 1875 (Vol. II., pp., 42, 55 and 79). The report was made after a visit to the sewerage systems of Europe, probably the earliest visit, and the first report of this kind made by an American engineer. As long ago as 1875, when the report was reprinted in this journal, copies of it were not available and it was necessary to transcribe it in the office of Mr. Chesbrough. An abstract of the report is given in Rafter and Baker's "Sewage Disposal in the United States," pp. 172-3, and also a more extended description than can be presented here of the efforts to purify the Chicago River prior to the inception of the great drainage canal.

as long as all of the sewage could be discharged into it, there would be no need of building an expensive canal for flushing the North Branch.

As finally constructed, the sewerage system differed considerably from the original plans. The more important of the changes were: The omission of the flushing pipes and the 16th St. canal, and the discharge of several of the sewers directly into the lake. It should be noted that the construction of the great drainage channel, now under way, will not correct this original error of emptying part of the sewers into the lake, an error which it is also worth noting was made against the advice of the engineer.

The first trouble, however, did not arise from the sewers entering the lake, but from the gradual accumulation of filth in the South Branch of the Chicago River. This accumulation the engineer had intended to prevent by constructing the 16th St. canal, but, as already noted, for some reason the commissioners had deemed it inadvisable to construct this canal. This offensive condition of the South Branch seems to have first attracted official attention in 1860, for the records show that in that year the Board of Sewerage Commissioners ordered Chief Engineer Chesbrough to investigate means for alleviating the nuisance and especially to find out what the chances were of getting rid of the foul water by the Illinois & Michigan Canal. This canal had been completed in 1847 from the Chicago River, at Bridgeport, to the Illinois River, at La Salle, 100 miles, and secured part of its water for the summit level in times of drought by pumping form the Chicago River at Bridgeport. This pumping was necessary for only about 45 days out of the year, but it had done much toward relieving the river from its filth at those times, and Mr. Chesbrough argued that until some more efficacious plan should be decided upon, the city should pay the canal officials to pump from the river enough water to keep it inoffensive, whether they needed the water for the summit level or not. He was probably led to urge this temporary expedient by the hope that the talk of cutting down the summit level of the canal, so that all the water for its supply could come from Lake Michigan, would materialize into some definite plan for the work. Of course, if a good current was set up in the South Branch and west through the canal by this cutting down of the summit level, the whole question which was troubling the city was settled.

It is worth noting that the complaints of the foulness of the river arose first not on account of the contamination of the water supply, but on account of the offensive odor. In the early winter of 1862, however, a combination of high water in the river and a southeast wind lowering the lake level, caused a very large amount of the river water to enter the lake, and complaints immediately arose of the foul smell and taste of the water supply. Despite the pumping into the canal, this nuisance became of increasing frequency, and finally in 1864-5 the city and the canal officials came to an agreement whereby the summit level was to be cut down, and all the water drawn from the lake. Work was begun in 1865, and, after many delays, was completed in 1871.

All this work had been done to relieve the South Branch, and, indeed, it was not until nearly 1870 that any trouble began with the North Branch, owing to adherence to the policy of not discharging sewage into it until it was absolutely necessary. In 1870 only about 5% of the total sewage of the city entered the North Branch, but numerous distilleries and tanneries had been erected along its banks, and the waste from them was rapidly making the water as foul as that of the South Branch. The deepening of the canal was expected to cleanse the South Branch, but it would not help the North Branch. It was decided, therefore, to construct a conduit from the lake to the upper waters of the North Branch, and pump water into the river or into the lake through this conduit, as might be required, for the purification of the river. This conduit was built along Fullerton Ave., and is known as the Fullerton Ave. conduit.

The Fullerton Ave. conduit was completed in 1880, nearly six years after work was first begun. It was a brick tunnel 12 ft. in diameter, and 11,898 ft. long. The bottom of the tunnel from the river to Racine Ave., 4,270 ft., was level and 13 ft. below datum. A short distance east of Racine Ave. it dropped to a grade 27⅔ ft. below datum, and thence continued in a series of descending grades to the lake shore shaft, where it was 54½ ft. below datum. From this point to the lake shaft, 1,000 ft., the conduit was level. The pumping machinery was at the river, and consisted of two screws similar to an ordinary propeller, which were fixed on a horizontal shaft and operated to force the water in either direction. The rated capacity of these screws was 24,000 cu. ft. per minute. How this conduit operated for the purpose intended will be noted later.

Returning now to the deepening of the Illinois and Michigan Canal in 1871, it was of course expected that when the work was finished there would be no further trouble, and indeed for some months everything worked charmingly. Difficulties were approaching, however, from several directions. It was soon discovered that the difference between the level of the canal at the summit and at the lake was so small and the current west so slow, that a southwest wind lowering the lake level would change the current to run east. A very heavy rainfall would also fill the canal and set the current east. At the best the current was sluggish. The greatest trouble, however, arose from the construction of the Ogden-Wentworth Canal. This canal was built partly for drainage purposes, by which the low-lying land along the Desplaines River north of Summit could be reclaimed, and partly to supply additional dock and harbor facilities. It was entirely a private enterprise. The canal was, in fact, an extension of the West Fork of the South Branch west to a connection with the Desplaines River just north of Summit, or just where the waters coming from the north turn west

towards the Illinois River valley. The result of this canal was that a very considerable part of the waters of the Desplaines, instead of flowing west by the natural channel, came east by the new canal, and, emptying into the South Branch of the Chicago River, caused a current east. In other words, the Ogden-Wentworth Canal undid all the work which had been done in deepening the Illinois & Michigan Canal, as far as its effect upon the purification of the river was concerned.

A long and bitter wrangle arose between the owners of the canal on one hand and the city and state officials on the other regarding the right of the canal people to construct and use their canal. This dispute was finally patched up by an agreement for the construction of a dam which would prevent the waters of the Desplaines from entering the canal at all times. The first dam was built in 1877, and in 1885 a new dam was constructed. This dam, however, restrained the water from flowing into the Chicago River only at the low stages of the Desplaines River. As a matter of fact, at times of high floods 75% of the Desplaines River waters came through Chicago as they did before dams were built. It was found, however, that something had to be done to maintain the current west through the South Branch of the Chicago River and the Illinois & Michigan Canal, and after much study it was decided to rebuild the old pumping works at Bridgeport which had been removed after the deepening of the Summit level.

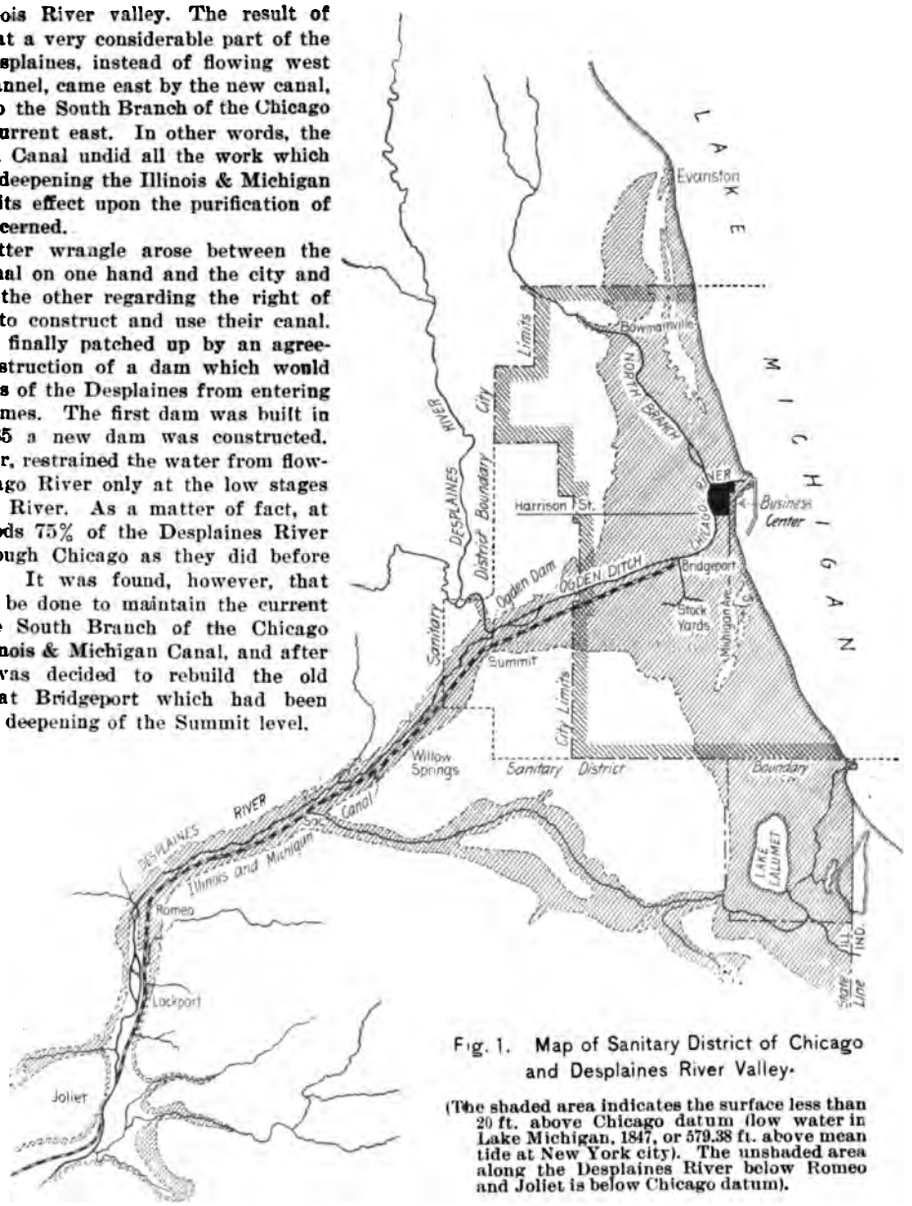


Fig. 1. Map of Sanitary District of Chicago and Desplaines River Valley.

(The shaded area indicates the surface less than 20 ft. above Chicago datum (low water in Lake Michigan, 1847, or 579.38 ft. above mean tide at New York city). The unshaded area along the Desplaines River below Romeo and Joliet is below Chicago datum).

Meanwhile, the Fullerton Ave. conduit had not done what it was expected to do, that is, keep the North Branch clear of offensive sewage. As soon as it was finished the city began to discharge sewage into the North Branch, and the waters here soon became almost as filthy as those of the South Branch. To be sure, the conduit had delayed the fouling of the water, but it could not prevent it in the end. Neither had the Bridgeport pumping plant succeeded in benefiting the condition of the South Branch much. The city of Chicago therefore found itself, at the end of 1880, after 25 years of struggling to get rid of its sewage and preserve its water supply uncontaminated, looking for some means of purifying the waters of this river from its filth and preventing a repetition of the great epidemics of 1848 and 1854, which had led to the construction of the first system of sewers.

In 1880 the Citizens' Association of Chicago, through the newspapers and printed pamphlets, began the work of creating and fostering a public sentiment which should demand better drainage for the city. This agitation resulted in the creation of a Drainage & Water Supply Commission by the City

Councils in January, 1886. The first commission was appointed immediately by Mayor Carter H. Harrison, and consisted of Mr. Rudolph Hering, M. Am. Soc. C. E., as Chief Engineer, and Mr. Benezette Williams and Mr. Samuel G. Artingstall, M. Am. Soc. C. E., Consulting Engineers This commission made a thorough study of the conditions and presented a preliminary report in January, 1887. Owing to lack of funds, no final report was ever presented. Summed up in the fewest words, the report recommended the construction of a canal to carry the sewage diluted with water from Lake Michigan west into the Desplaines River, and thence into the Mississippi River.

As a result of this report two bills providing an adequate system of drainage for the city of Chicago were introduced into the Illinois State Legislature at the session of 1886-7. One of these was known as the Winston bill, and provided for raising the money necessary for constructing the proposed channel by special assessment on the property benefited. The other bill was known as the Hurd bill, and created a metropolitan district with power to issue bonds based on taxation to construct the required works. After several months' study by the Senate and House Committees, and then by a special commission of two members each of the House and Senate and the Mayor of Chicago, the Hurd bill, in a slightly modified form, was passed by the legislature and became a law July 1, 1889. Under this law the boundaries of the Sanitary District of Chicago were fixed Oct. 14, 1889, and the first Board of Trustees was elected Dec. 12, 1889.

Passing over the numerous internal dissensions with which the trustees frittered away the best part of two years with nothing definitely accomplished, we will endeavor to trace briefly the work of selecting a route for the proposed channel. It is the accepted geological teaching that the Great Lakes at one time emptied into the Gulf of Mexico, and perhaps at a still earlier date were an arm of the great southern sea bordering the North American continent and extending up through the present Mississippi Valley. As time passed and the southern ocean receded toward its present boundaries, the lake waters lowered until finally the gradually decreasing stream toward the Gulf of Mexico ceased altogether, and the entire outlet of the inland waters was through the St. Lawrence River. It is unimportant for the present purpose to trace the causes and progress of this movement, but the action left a rock-hewn trough through the watershed between Lake Michigan and the Mississippi Valley which is now occupied in part by the Desplaines River. This trough is indicated in a general manner by the maps Fig. 1 and Fig. 2, and of course was the route which naturally suggested itself for the canal.

The selection of a canal route in this limited available territory should have been one of no very great difficulty had the engineers been allowed to go at the work in a business-like manner, but this was not done. In the first place, Mr. L. E. Cooley, the first Chief Engineer, was interfered with in his surveys and ordered to report a route without sufficient time to secure the necessary information upon which to base plans and estimates. This he refused to do, and finally resigned his office. Mr. Wm. E. Worthen M. Am. Soc. C. E., was then appointed Chief Engineer, and he submitted two routes in a report dated Jan. 10, 1891. The Trustees adopted one of these routes April 4, 1891, but did nothing further. Mr. Worthen resigned his office soon after, and Mr. Samuel G. Artingstall, M. Am. Soc. C. E., was appointed Chief Engineer. Mr. Artingstall surveyed and submitted to the Trustees four routes, and on Sept. 16, 1891, the ordinance of April 4 was annulled and one of these routes was adopted, but no further action was taken. Three of the Trustees then resigned, and in November others were elected to fill the vacancies, and the new Board of Trustees was organized Dec. 8, 1891. On Jan. 16. 1892, Mr. Artingstall resigned, and Mr. Benezette Williams was appointed to fill the position. Mr. Williams submitted five routes for consideration, one of which, after slight modifications, was adopted. It is along this route that the channel is now being constructed.

sections should not be such as to cause erosion of the bottom or sides, an action apt to take place in sandy soil, or in soil which may become soft by prolonged contact with water.

A narrower and deeper channel would have been less costly than the one now being constructed, but the Sanitary District law fixed 160 ft. as the minimum width, which limitation determined the width of the rock channel, and the earth channel was made of dimensions giving a corresponding capacity.

The river diversion channel is 200 ft. wide on the bottom, and has side slopes of 1½ to 1, and a grade of generally 0.012%, or about 1 ft. in 8,335 ft. Further details of the main drainage and river diversion channels and their relative location in respect to the Desplaines River, the Illinois & Michigan Canal and the various railway lines are shown by the map. The profiles show the depth of excavation at different points and the relative amounts of earth and rock excavation.

For the purpose of letting the contracts the material to be excavated was divided into two classes, rock and "glacial drift." The first term explains itself, but the character of the material termed "glacial drift," this being an entirely arbitrary classification, needs some further explanation. As defined in the specifications, "glacial drift shall comprise the top soil, earth, muck, sand, gravel, clay, hardpan, boulders, fragmentary rock displaced from its original bed, and any other material that overlies bed rock." In fact, all these materials are found in all degrees of intermixture, from soft black muck, which can be pumped with centrifugal pumps, to a conglomerate of sand, gravel, clay, and boulders cemented together with almost the hardness of rock, and only to be excavated by means of the strongest steam shovels, and sometimes even requiring blasting to break it up. The exact character of the material on each contract section will be more exactly set forth in following articles describing the methods of excavation adopted by the different contractors.

The entire 29 sections are now under contract. Sections 1 to 14, inclusive, were put under contract in July, 1892; sections A to F, inclusive, late in 1892 and early in 1893; sections I to M, inclusive, in December, 1893; sections N and O, in May and June, 1894, and section 15 in August, 1894. On a considerable number of sections the original contractors have given way to new firms of contractors either through the forfeiture and reletting of their contract or its transfer by sale, and these changes will be noted as far as seems needful in following articles. In this article, the names of the present contractors, only, are given in the accompanying table. (Table 1.)

The significance of these totals of earth and rock to be excavated is not easily realized, even by engineers. Compared with the excavation required in other great canals, these figures given in round numbers stand as follows:

	Total excav., cu. yds.
*Panama Canal	200,000,000
North Sea and Baltic Canal	104,600,000
*Nicaragua Canal	70,000,000
Corinth Ship Canal	11,000,000
Chicago Main Drainage Channel	40,000,000
Suez Canal	80,000,000

* Not yet constructed.

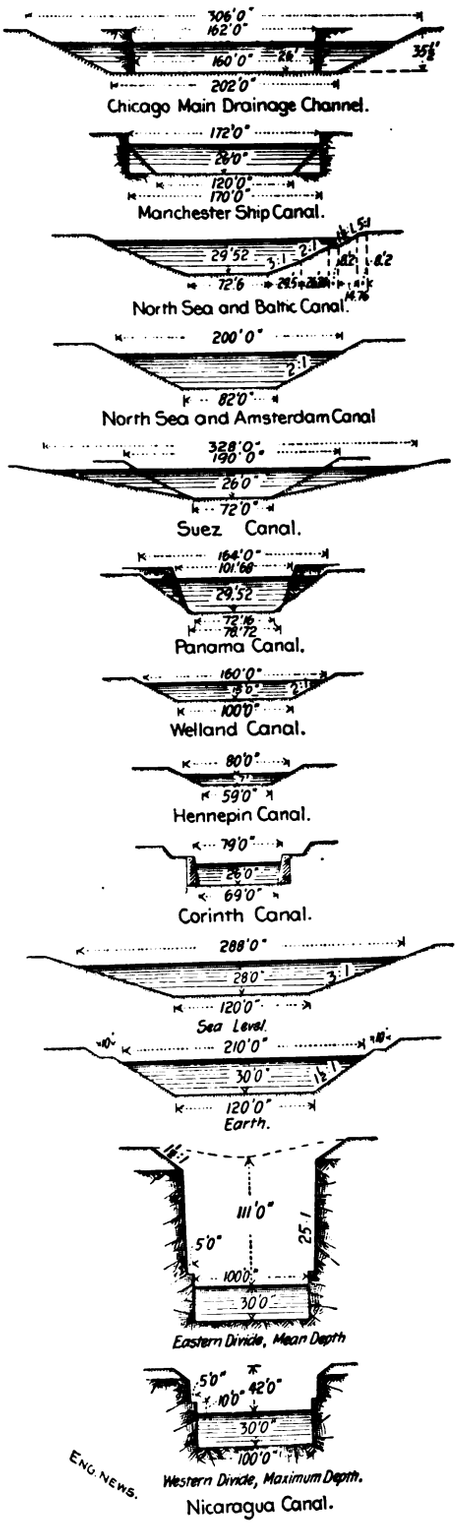


Fig. 4. Cross-Sections of the Great Canals of the World.

TABLE I.—GIVING NAMES OF CONTRACTORS, CUBIC YARDS OF EXCAVATION AND PRICE PAID FOR EXCAVATION FOR EACH CONTRACT SECTION OF THE CHICAGO MAIN DRAINAGE CHANNEL, COMPILED FROM THE LATEST ESTIMATES (DEC. 31, 1894) OF THE ENGINEER CORPS OF THE SANITARY DISTRICT OF CHICAGO.

Note.—The totals of cost in the last column include all the miscellaneous constructions, as trestles, riprap, etc., of each section.

Names and addresses of contractors.	Section.	Glacial drift. Main channel cu. yds.	Glacial drift. Price per cu. yd., cts.	Glacial drift. River diversion, cu. yds.	Rock. Cu. yds.	Rock. Price per cu. yd., cts.	Retaining wall. Cu. yds.	Retaining wall. Price per cu. yd.	Total cost.
Brighton Division.									
McMahon & Montgomery, 425 N. Halsted St., Chicago.	O	1,648,743(a)	21	.....	.....	..	.....	....	$344,783
Hayes Bros., 32d St. and Maplewood Ave., Chicago...	N	1,113,843	23	.....	.....	..	.....	....	256,184
The Heidenreich Co., the Rookery, Chicago.....	M	722,850	21.7	.....	.....	..	.....	....	156,588
" " " " " "	L	1,101,881	19.7	.....	.....	..	.....	....	217,071
Christie & Lowe, N. Y. Life Bldg., Chicago.....	K	1,155,957	25	.....	.....	..	.....	....	288,989
" " " " " " "	I	1,128,849	25	.....	.....	..	.....	....	284,962
Totals for Brighton division.....		6,873,123	..	.....	.....	..	.....	....	$1,548,848
Summit Division.									
Gahan & Byrne, Summit, Ill.	H	1,077,032	29	.....	.....	..	.....	....	$312,339
" " " " " "	G	1,363,975	28	.....	.....	..	.....	....	381,941
Weir & McKechney, Summitt, Ill.....	F(b)	1,093,653	29½	66,914	16,724	90	.....	....	348,749
Angus & Gindele, Summit, Ill.....	E	1,813,659	27	74,334	78,765	70	.....	....	(c)606,613
E. D. Smith & Co., Romeoville, Ill.....	D	1,877,721	26 7-16	.....	137,694	100	.....	....	636,997
Western Dredging & Improvement Co., Summit, Ill....	C	1,887,755	23½	.....	.....	..	.....	....	486,319
Totals for Summit division.....		9,113,795	..	141,248	233,183	..	.....	....	$2,772,959
Willow Springs Division.									
Heldmaier & Neu, Mount Forest, Ill.....	B	1,576,828	27	212,210	.....	..	.....	....	$485,120
" " " " " "	A	2,576,508	30⅝	271,855(d)	4,188	80	.....	....	913,739
Griffith & McDermott, Willow Springs, Ill.....	1	1,173,751(f)	42.9	174,655(e)	536,024	80	66,967	$2.90	1,286,190
McArthur Bros., W. C. T. U. Temple, Chicago.....	2	729,489(g)	50	119,233(h)	472,624	80	37,668	3.25	922,256
Gilman & Co., Willow Springs, Ill.....	3	417,624(i)	56	.....	764,358	76	13,307	3.25	836,769
McArthur Bros., W. C. T. U. Temple, Chicago.....	4	999,655(k)	49	106,803	359,677	80	58,564	3.25	1,022,199
Totals for Willow Springs division.....		7,464,355	..	884,756	2,136,071	..	176,506	....	$5,466,276
Lemont Division.									
The Qualey Construction Co., Sag Bridge, Ill.....	5	1,064,021	27	.....	265,833	..	73,424	$3.25	$765,746
Mason, Hoge & Co., Romeoville, Ill.....	6	685,156	27	118,808	549,118(l)	73½	33,736	3.25	755,530
" " " " " "	7	184,555	26	97,930	931,307(m)	74½	3,957	3.25	827,485
Mason, Hoge, King & Co., Romeoville, Ill.....	8	43,576	26	57,867	1,262,749(n)	74¾	.....	....	1,028,130
Halvorsen, Richards & Co., Lemont, Ill.....	9	73,693	26	40,741	1,022,310(o)	76.9	.....	....	820,185
E. D. Smith & Co., Romeoville, Ill.....	10	31,104	25	30,310	1,199,546(p)	80	.....	....	1,022,850
Totals for Lemont division.....		2,082,105	..	345,655	5,230,863	..	119,052	....	$5,219,924
Lockport Division.									
Mason, Hoge & Co., Romeoville, Ill.....	11	44,032	30¼	11,739	1,001,183(q)	79¼	.....	....	$840,519
" " " " " "	12	60,000	30¼	11,739	1,000,500	73	10,000	$3.50	857,007
" " " " " "	13	35,000	26	.....	1,053,700	74¾	20,000	3.50	866,740
Smith & Eastman, Lockport, Ill.....	14	379,255	36(r)	.....	1,023,500	73	22,000	3.25	928,593
Wright, Meysenberg, Sinclair & Carry, Lockport, Ill..	15	36,000	19	.....	639,700	59	37,400	2.35	472,453
Totals for Lockport division.....		554,287	..	17,495	4,718,583	..	89,400	....	$3,965,012
Grand totals for 29 sections under contract.....		26,087,665	..	1,389,154	12,318,700	..	384,958	....	18,973,025
				Estimated cost of work contemplated but not contracted for..					3,883,899
				Cost of right of way					2,600,000
				Cost of administration					1,828,238
				Estimated total cost of canal.....					$27,303,216

(a) 132,009 cu. yds. collateral channel at 19.9 cts. per cu. yd. (b) 504,293 cu. yds. of the main channel and all of the river diversion channel were excavated by the first contractors, Ricker, Lee & Co., at 23¾ cts. per cu. yd. The figures of totals in the last column are obtained on the basis of 23¾ cts. per cu. yd. for the entire work. (c) This is figured on original prices of first contractors, Streeter & Kenefick. (d) 122,342 cu. yds. of this was material dredged from Desplaines River bed. (e) 10,162 cu. yds. of this is classed as river improvement. (f) 109,540 cu. yds. of this was excavated for 27 cts. and 11,926 cu. yds. for 30⅝ cts. (g) 29,625 cu. yds. of this was excavated for 28 cts. per cu. yd. (h) 29,516 cu. yds. excavated at 28 cts. per cu. yd. (i) 73,310 cu. yds. of this was excavated for 27 cts. per cu. yd. (k) 48,593 cu. yds. excavated for 27 cts. per cu. yd. (l) 17,857 cu. yds. river diversion. (m) 43,088 cu. yds. river diversion. (n) 99,434 cu. yds. of this river diversion. (o) 16,894 cu. yds. river diversion. (p) 58,276 cu. yds. river diversion. (q) 11,483 cu. yds. river diversion. (r) 166,210 cu. yds. at 20 cts. per cu. yd.

The cross section of the Chicago Drainage Channel compared with the characteristic cross sections of these and other well-known canals is shown in Fig. 4.

The officers to whom the task of carrying out this great work has been entrusted by the citizens of Chicago consist of a Board of nine Trustees, a Treasurer, Clerk, Attorney, and Chief Engineer. The present incumbents* are: Board of Trustees, Messrs. Frank Wenter, President; John J. Altpeter, William Boldenweck, Lyman E. Cooley, A. P. Gilmore, Bernard A. Eckhart, Thomas Kelly, Richard Prendergast, William H. Russell; Treasurer, Mr. Melville E. Stone; Clerk, Mr. Thomas F. Judge; Attorney, Mr. Geo. E. Dawson; Chief Engineer, Mr. Isham Randolph. Mr. Thos. T. Johnston is First Assistant Chief Engineer, and Mr. Uri W. Weston is Superintendent of Construction.

* At the city election on Nov. 5, 1895, a new Board of Trustees was elected to serve for five years. Messrs. Boldenweck, Eckhart, Wenter and Kelly, of the old board, were re-elected, and new members were elected as follows: Messrs. Zina R. Carter, James P. Mallette, Joseph C. Braden, Thomas A. Smyth and Alexander J. Jones.

CHAPTER III.

THE SPECIFICATIONS FOR THE WORK.

HE first work of the Board of Trustees after deciding upon the routes and cross-sections of the main drainage and river division channels was to formulate a general policy for carrying out the construction, and to prepare plans and specifications preparatory to letting the contracts. It was decided (1) to put the more difficult portions of the work under contract first, and (2) to divide the channel into a large number of short sections, and limit the number of sections to be let to a single contractor. The idea was, of course, to give the contractors for the rock sections the greater length of time in which to complete their work, which the greater hardness of the material necessitated, and to bring the size of the separate contracts well within the ability of the ordinary contractor to handle, thus making possible a widespread competition for the work. The reduction of the size of the contracts and their division among a number of contractors have also been of decided advantage in the disputes which have arisen between the contractors and the trustees. For example, in the trouble arising over the cemented gravel and clay on Section F—which will be touched upon in a later article—the work was taken from the original contractors and relet without at all affecting or involving a delay in the work on the neighboring contract sections. If these contractors had controlled the work on a dozen sections, it will readily be seen that the delay in the work of the channel as a whole, and the difficulties of adjusting the dispute, might have been immensely increased. As it was, the whole difficulty began and ended with a single contractor and a single section of the canal less than a mile in length.

In drawing up the earlier specifications for the excavations, two classifications of material were adopted, viz., "solid rock" and "glacial drift," the latter comprising all material either hard or soft other than solid rock. The contractors were required to base their bids for excavating glacial drift on the results of borings 3 ins. in diameter made along the whole length of the line. It had been intended by the first Chief Engineer, Mr. L. E. Cooley, to sink a series of test pits instead of these small borings, but this plan was overruled by the first Board of Trustees, and the pits were never sunk. The error of this action of the Trustees had far-reaching results, for, owing to a combination of peculiar material and inefficient inspectors to record the borings, an entirely misleading idea was obtained of the hardness of the glacial drift on certain sections. In fact, it is doubtful if, with the most careful attention to conducting and recording the borings, they would have indicated with any truthfulness the exact character of some of this material. From the information obtained from these borings, however, the relative quantities of solid rock and glacial drift to be excavated were calculated, and specifications were prepared.

As far as possible, with due consideration to the varying material and conditions, the terms of the specifications were made uniform for both the solid rock and the earth channels. In the following paragraphs the principal provisions of the specifications for both classes of work have, therefore, been combined, and such explanations are given as are necessary to make the differences clearly understood.

A profile of the surface of the ground approximately on the line of the channel was furnished to each bidder, accompanied by the statement that although it was considered that these profiles were approximately correct, they did not pretend to be absolutely so. The relative quantities of glacial drift and rock were also stated to be approximate, and the contractor was warned that he took all risk in the variation of these quantities from the figures given. The results of the borings referred to were indicated on the profile. Before the entire canal had been put under contract, trouble had arisen over the quality of the material encountered, it being claimed by the contractors that the borings were inaccurate, and the specifications for subsequent contracts were modified to state, in addition to what it said above, that bidders must satisfy themselves as to the quantity and quality of the materials. In the contracts for Sections (G to O), inclusive, the term "glacial drift" was changed to "excavation."

Continuing, the specifications stated that when the channel was in rock, the sides were required to be worked out with channeling machines from top

to bottom. If the depth of the rock did not exceed 16 ft., subsequently changed to 12 ft., but one cut of the channeling machine was to be made, and if it did not exceed 24 ft. but two cuts were to be made. Under no circumstances were there to be more than three cuts. Each of the succeeding cuts was to have an offset of 6 ins. from the cut immediately preceding. The rock was to be taken out in two or more stopes or lifts, as the contractor desired. Where the channel was partly in earth and partly in rock, the earth was to be so excavated as to leave a berm on top of the rock equal in width to three-eighths of the depth of the rock surface below a level of 5 ft. above datum, provided that in no case should this width be less than 5 ft. On this berm the retaining wall was to be built.

When the channel was entirely in earth, the width on the bottom was to be 202 ft., and the slope on the sides 2 ft. horizontal to 1 ft. vertical, except in the temporary channel sections F. to O, inclusive, where the width of the bottom was to be 110 ft. The manner of excavation was left to the will of the contractor, but the disposition of the spoil was limited to certain places. The location of the spoil banks varied for different parts of the channel. All materials, such as trees, fences, buildings, etc., within 150 ft. of the center line of the channel were to be removed by the contractor and to become his property. The contractor was required to provide all pumping machinery and bear all the expense of draining the channel until the whole work was fully completed.

Wherever the top of the rock at the sides of the channel was below 5 ft. above datum, it was specified that retaining walls of masonry laid in cement mortar were to be built. If the bottom of the channel was in rock, the walls were to be founded on rock, and if the bottom was in earth, the walls were to be founded upon a footing made in a trench dug not less than 1 ft. below grade, and as much deeper as the engineer might specify. The footing was to project 1 ft. beyond the face. The top of the wall was to be 5 ft. above datum and 4 ft. wide, except on Sections 14 and 15, where the channel is in embankment, and a top width of 6 ft. is specified. The thickness of the walls at the bottom was to be not less than one-half their height, providing this was not less than the width at the top plus the total batter. The backs of the walls were to be stepped, and the fronts smooth and flush with the edge of the channel at the bottom. The width across the channel between the inner edges of the tops of the walls was to be 166 ft. The cross-section of the walls on Sections 14 and 15 differs from the above in that the cross-section is designed to retain water.

The material used in constructing the walls was to be stone taken from the channel. All stone were to be laid on their quarry beds in courses not less than 12 ins. and not more than 30 ins. in thickness. No stone was to be less than 12 ins. thick. All stones were to be laid so as to break joints with the stones in the course below. American natural cement mortar, made of equal parts cement and sand, was to be used in laying the masonry. It was intended at first to lay the retaining walls dry, but upon getting down to the rock it was found to be of such poor quality, that in the opinion of the engineers it was not suitable for dry masonry work, and the specifications were altered to provide for cement mortar masonry. The space between the retaining walls and the bank of the excavation was to be filled with broken stone.

All along the river diversion work, the specifications required a levee to be constructed between the river channel and the drainage channel. This levee was to be built of spoil from the two channels and carried to a height well above that of the highest known high water mark. Where necessary the levee was to be carefully riprapped on the slope next the river diversion channel. There were about 19 miles of levee on the canal.

Strict regulations were drawn regarding the responsibility of the contractor for accidents, damages to property, etc. No subcontracts were allowed. This stipulation, it may be noted here, was repeatedly violated, many of the contractors subletting a very large portion of their work. A thorough system of measuring the quantities excavated and paying for the same was specified. Two estimates were to be made each month, and payment made for a yardage of 87½% of the estimate. The specifications also provided that:

If the manner of conducting the work is such that at the time of making any progress estimate a markedly greater proportion of the top material has been excavated than of the bottom material, then the Chief Engineer shall in making such estimates ascertain what amount has been excavated up to that time of any material lying above, and what below, a horizontal plane dividing the mass of said class of material into equal parts; and if the upper portion exceeds the lower, then the total amount of material found to have been excavated shall be reduced by 10% of said excess, and estimates or certificates issued on the remainder, with the percentage deductions provided, viz., 12½%.

The work required to be done each month was to be not less than such a proportion of the whole work as one month was of the total number of months agreed upon for the completion of the work. The first two months from the date of contract and the last two months before the date of completion were each held to count one month in progress.

Regarding the failure of the contractor to keep up to the monthly progress requirement, the specifications read as follows:

If the work to be done under this contract shall be abandoned, or if it shall be assigned by the contractor, or if he loses control of the work from any cause, excepting acts of God and the public enemy, or if the rate of progress is not such as to insure its completion within the time specified, or, if at any time the Chief Engineer shall be of the opinion, and shall so certify in writing, that said work, or any part thereof, is unnecessarily and unreasonably delayed, or

that the contractor is willfully and persistently violating any of the conditions or covenants of this contract, or is not executing said contract in good faith the Sanitary District of Chicago shall have the power to notify said contractor to discontinue all work, or any part thereof, as may be designated, and shall thereupon have the power either to complete said work by contract or to employ such men and teams, and to obtain such machinery, implements and tools, and to purchase such material as the said Chief Engineer may deem necessary to complete the work herein described, or any part thereof. And in so doing said chief engineer may use such tools, implements and materials as may be found upon the line of said work. The cost of doing such work shall be charged to the said contractor, and any moneys that may then be due, or may at any time thereafter become due, to said contractor under and by virtue of this contract, shall be applied to the payment of such cost, so far as same shall suffice therefor, and the remainder of the cost of so completing said work, if any, shall be paid by said contractor on demand.

The terms of this last clause of the specifications are given in full, for upon them have been based the actions of the Board of Trustees in declaring certain contracts forfeited and reletting them to new contractors.

The operation of the forfeiture clauses in the specifications has been satisfactory, as evidenced by the successful abrogation of the original contracts for eleven of the contract sections and the reletting of the same.

A pretty complete understanding of the requirements of the work and the conditions under which it was undertaken by the contractors will be obtained from the foregoing paragraphs. The principal difficulties which have arisen came from the insufficient information furnished regarding the quality of the material on certain sections. In the articles immediately following this, the description of the methods adopted for doing the work on each of the contract sections, beginning at the eastern terminus of the canal, will be described.

It should first be noted, however, that for the purpose of carrying out the engineering work the whole channel was divided into four "divisions," which, commencing at the eastern terminus of the channel, are known as the Summit, Willow Springs, Lemont and Lockport divisions. Each division is in charge of a division engineer, who has his office at the town from which the division is named. The present Division Engineers are: Mr. E. R. Shnable, Summit Division; H. B. Alexander, Willow Springs Division; H. A. Miller, Lemont Division, and C. L. Harrison, Lockport Division.

CHAPTER IV.

THE SUMMIT DIVISION.

HE Summit Division of the Main Drainage Canal extends from the beginning of the channel, at Robey St., to the west end of Section G, a distance of about 7½ miles. Throughout the entire length of this division the channel is in earth and is 110 ft. wide on the bottom, with side slopes of 2 ft. horizontal to 1 ft. vertical. Mr. E. R. Shnable is the engineer in charge of this division,* and to him we are indebted for much aid in securing the matter from which the following articles on Sections O to G, inclusive, have been prepared.

Sections O and N.

In accordance with the policy of the Board of Trustees to let the contracts for the more difficult portions of the work on the channel first, the contracts for Sections O and N, beginning at the eastern terminus, were not let until May 2, 1894.

In bidding for the excavation on these two sections, the contractors were given the alternatives of spoiling the material on the right of way or of conveying entirely from the right of way and disposing as they saw fit such portions as were not required in constructing levees and grading the neighboring land. The amount of excavation called for was 1,648,743 cu. yds. on Section O and 1,113,843 cu. yds. on Section N. For Section O there were 15 bids and for Section N ten bids, seven bids and four bids, respectively, giving prices for each of the alternative methods of disposing of the spoil.

The numerous streets and railways crossing this part of the channel, and the certainty that in the near future the channel would have to be enlarged, determined the Trustees to the opinion that the best interests of the district required the removal of the spoil from the right of way. For this proposition the lowest bidders were Green's Dredging Co., 19.9 cts. per cu. yd. for Section O, and Hayes Bros., 23 cts. per cu. yd. for Section N. Both Hayes Bros. and McMahon & Montgomery bid 23 cts. per cu. yd. for Section O, which price was next lowest after that of Green's Dredging Co. There was some question as to the formality of Green's Dredging Co.'s bid, and this, added to the desirability of having the two sections worked conjointly, or at least in close harmony with each other, led to a consolidation of forces by the three firms of contractors named, and on May 2 the contract for Section O was let to McMahon & Montgomery, and for Section N to Hayes Bros., with the understanding that Green's Dredging Co., the Fitzsimons & Connell Co., and the Chicago Dock & Dredging Co., should be associated in the work and sign the contracts with them. The price at which the work for Section O was let was 19.9 cts. per cu. yd. for material to be removed from the right of way, and 24 cts. per cu. yd. for the material to be used for grading and other purposes on the section. As it was calculated that 1,103,783 cu. yds. were to be removed and 425,000 cu. yds. retained on the section, these prices gave an equivalent price of 21 cts. per cu. yd. for the entire section. The price for the work on Section N. was 23 cts. per cu. yd.

Besides the main channel excavation, the work on Section O included the construction of a collateral channel 60 ft. wide on the bottom and 12 ft. deep, connecting the main channel with the West Fork of the South Branch of the Chicago River. This work was necessitated by the group of railway tracks which cross the main channel about the middle of Section O. Some trouble and delay were anticipated in securing the right of way underneath these tracks, and as it was not desirable to stop work during this delay, the Trustees decided to cut a collateral channel, and, after completing the main channel east of the track, to take the dredges along the West Fork to the point C (Fig.5), and thence to the main channel at the point B west of the tracks, and continue west toward D. In addition to affording a temporary passage for the dredges, it was considered that the collateral channel would be useful to vessels desiring to pass from the West Fork to the main channel, when the latter was open for navigation. The price for excavating the collateral channel was the same as for the main channel work, 19.9 cts. per cu. yd.

At the beginning of the work, the contractors, McMahon & Montgomery and Hayes Bros., en-

*Previous to the reorganization of the engineer corps of the canal and the reduction of the number of "divisions" from five to four, Mr. Alex. E. Kastl, M. Am. Soc. C. E., had charge of Sections O to I, inclusive, under the name of the Brighton Division. In the reorganization M. Kastl was transferred to the main office of the Sanitary District, and his division merged into the Summit Division under the charge of Mr. E. R. Shnable. We wish to acknowledge much aid received from Mr. Kastl during his charge of the Brighton Division.

tered into an agreement whereby the latter firm was to remove the top soil down to hard material, and do the necessary grading and building of embankments on both sections, while the former firm was to excavate the hard material with dredges, and convey it out into Lake Michigan and dump it. Work was begun on Section O in May, 1894, with wheel scrapers and dump carts for removing

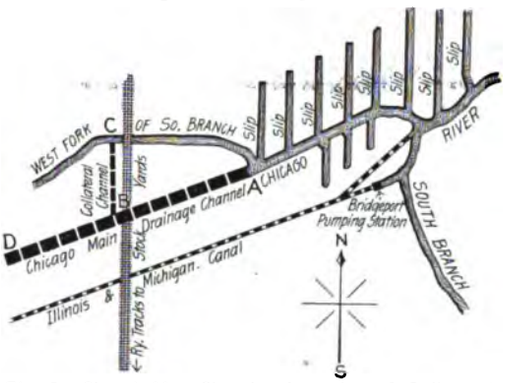


Fig. 5. Sketch Map Showing Location of Collateral Channel on Section O.

the top soil, and dipper dredges for handling the hard material. By the end of the month three dredges, four tugs and thirteen scows were at work, and this plant was increased to five dredges and 17 scows in June. A view of these dredges just as they had got well into work near the Chicago River is shown by Fig. 6. This view is looking east toward the city and Lake Michigan.

The average amount of material excavated by each dredge per ten hours, and the average scow load for five months were as follows:

	Excavation, cu. yds.	Scow loads, cu. yds.
July	860	...
August	780	230
September	520	186
October	560	181
November	460	...

In considering these figures attention should be called to the fact that during all the season the dredges were worked at close quarters, and therefore not always to the best advantage. Indeed, at one time it became necessary for one dredge to cut a channel ahead, casting the material to one side, in order to make room for the other dredges, and thus some of the material was handled twice. All this was caused by delay in securing the right of way by the Trustees.

Owing to the method of working, no figures of the output of individual dredges could be obtained, and the above figures assume each dredge to have done the same work. The following figures show the largest week's work done by each dredge:

Dredge.	Total No. scows loaded.	No. 10-hr. shifts worked.	Total cu. yds. exc.	Cu. yds. exc. per 10-hr. shift.
No. 3	36	6	6,600	1,100
No. 6	40	12	9,200	770
No. 9	48	6	9,200	1,530
No. 13	28	6	5,350	890

Dredge No. 9 is the large A-frame dredge shown in the foreground of Fig. 6, and dredge No. 6, which was considered on the whole, best adopted to the work, is shown in Fig. 7. This dredge was built by the Excelsior Iron Works, of Chicago, and is briefly described as follows:

The hull is 85 ft. long, 32 ft. wide and 8½ ft. deep, and is built of 8 × 12-in. oak timbers thoroughly braced together. Lengthwise of the hull run two steel trusses, which carry at their forward ends a cross girder supporting the upper mast box. These longitudinal girders are 17 ft. high and are built of ⅝-in. plates and 4 × 4 × ½-in. angles. A strong system of lateral bracing holds them firm laterally. Braced to the longitudinal girders are the casings for the forward spuds, which are 2 × 2-ft. oak timbers 30 ft. long shod with a cast iron shoe. These spuds can be raised by hand, but ordinarily they are operated by 20-in. diameter steam cylinders. The rear spud is operated in a similar manner, but is somewhat smaller than the side spuds.

The upper end of the crane is 38 ft. above the

Fig. 6. Dipper Dredges at Work on Section O, Near Eastern Terminus of Canal.

McMAHON & MONTGOMERY, Contractors, Chicago.

bottom mast box, and it is built of 1½-in. steel plates and 4 × 6 × ½-in. angles. The crane sheaves are 48 ins. and 38 ins. in diameter, and are mounted on a 3½-in. shaft, and the crane trusses are fastened to the mast by top and bottom castings. This mast is 9 ins. in diameter, and is made of the best forged iron. The turntable is 17 ft. in diameter and is constructed of steel. The dipper has a capacity of 2 cu. yds. It is made of ⅜-in. steel, reinforced by wrought iron bands, and has a 1-in. steel cutting edge. All forgings belonging to the dipper, as bail, hinges, pins, etc., are of the best quality of iron obtainable. The dipper handle is 35 ft. long, and is made of oak timber, reinforced by steel cover plates, and is provided with cast steel racks with shrouded teeth.

The power machinery for operating the dredge consists of the usual swinging and dredge engines. A duplex reversing engine, with 7 × 12-in. cylinders, operates the swinging mechanism, and a duplex hoisting engine, with 14 × 16-in. cylinders, operates the dipper. The dredge engine is geared by spur gearing to the drums, both of which are provided with conical friction clutches operated by steel thrust screws. The hoisting drum is 30 ins. in diameter and the backing drum 14 ins. in diameter, and both have 42-in. faces. The boiler is of the locomotive type, 72 ins. in diameter and 13 ft. long, and has a 4½ × 5-ft. firebox. The total heating surface is 900 sq. ft.

A dredge precisely like this dredge in design and construction, but differing somewhat in size,

Fig. 7. Steam Dipper Dredge at Work on Section O.

EXCELSIOR IRON WORKS, Chicago, Builders.

was illustrated and described in detail in Engineering News of Sept. 14 and 21, 1893.

The methods adopted for removing the top soil were all simple, and call for but little mention. Wheel scrapers were extensively used on both sections. When the material was to be used in levee construction or grading on the right of way, no other conveyance than the scrapers was required, but for the material which had to be taken away dump cars, wagons, etc., had to be used. On Section N gondola cars were used to a considerable extent to carry the dirt from the right of way. Fig. 8 shows the manner of loading these cars with wheel scrapers. The railway track was laid parallel to the edge of the excavation, and these inclines were built at convenient points along the track. With this apparatus the average capacity of each wheel scraper, with a full working force

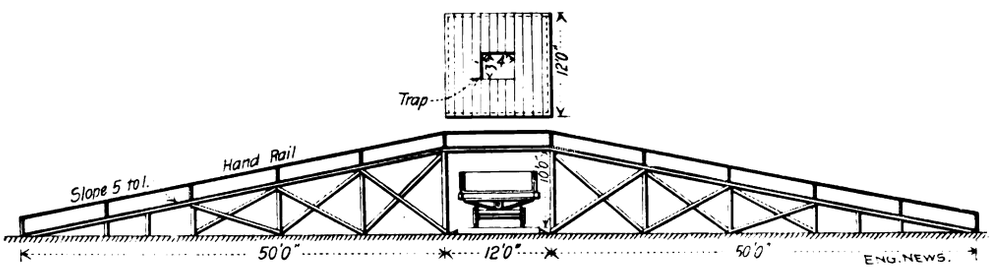


Fig. 8. Incline for Loading Gondola Cars, Section N.

HAYES BROS., Chicago, Contractors.

and under favorable conditions was 60 cu. yds. car measure per 10 hours. In actual work the output ran from 35 cu. yds. to 60 cu. yds. per 10 hours. The cost of each incline was about $100. The scrapers used were manufactured by the Western Wheel Scraper Co., Aurora, Ill.

Although the intention has been, as stated above, to remove the hard material throughout both Sections O and N by dredging, it seems likely that a portion at least of the work may be done by dry excavation.

Sections M and L.

The contract for Sections M and L was let to the Heidenreich Co., of Chicago, Ill., Dec. 23, 1893, and called for the excavation of 722,850 cu. yds. of glacial drift on Section M, and 1,101,881 cu. yds. on Section L, or altogether 1,823,731 cu. yds. of material. For Section L the contract price was 19.7 cts. per cu. yd., and for Section M 21.7 cts. per cu. yd., or an equivalent uniform price of 20.4 cts. per cu. yd. for both sections. With the exception of about 40,000 cu. yds. on Section 15, this is the lowest price received for glacial drift on the whole work. The material encountered corresponds very closely to that found on Sections O and N, being a rather hard, compact clay, covered with about 5 or 6 ft. of prairie soil. The channel is 110 ft. wide on the bottom, with 2 ft. horizontal to 1 ft. vertical side slopes. The area for the south spoil bank is 175 ft. in width and for the north spoil bank 227 ft., with 80 ft. berms between the canal and spoil bank on both sides.

To handle the earth at this low price the contractors resorted to a modification of the inclined plane and tipple often used in the coal regions. The cars running on this incline are loaded by steam shovel and hauled to the top and dumped by a winding engine of ordinary type. Fig. 9 shows the system of incline conveyors used, all the shovels and conveyors being headed west. Three of the conveyors are placed on the north bank of the canal, and follow each other in the order numbered, each making the cut corresponding to the number of the conveyor. Each of these cuts runs the entire length of the two sections. The gradual deepening and widening of the whole excavation by these successive cuts are clearly shown by the sections. After the third cut is made, the excavation is carried no deeper until this 20 ft. is taken off the whole width of the channel. On the south bank but one conveyor is used, but as this is operated day and night, while the others are operated days only, and as the south spoil bank is smaller than the other, the excavation of this conveyor is to that of the other three conveyors about as the volume of the south spoil bank is to the volume of the north spoil bank. The top lift of 20 ft. being removed, work is begun at the edge of the slopes of the bottom lift in

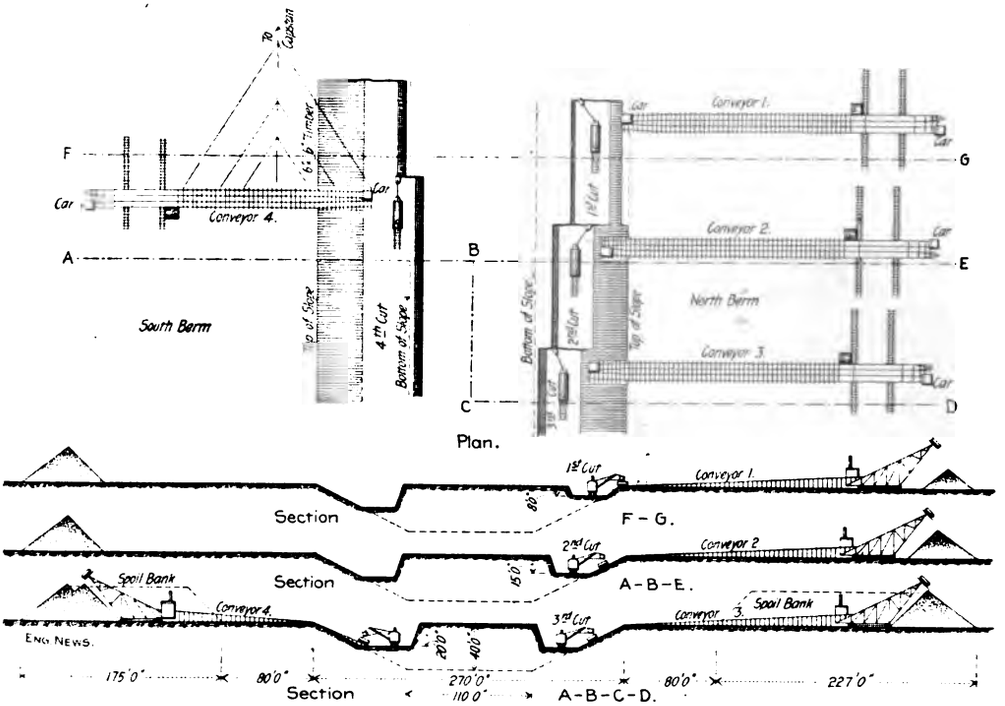


Fig. 9. Plan and Sections Showing Arrangement and Operation of Steam Shovels and Conveyors on Sections M and L.

THE HEIDENRICH CO., Chicago, Contractors.

exactly the same manner as before. In the plan, Conveyor No. 4 shows the attachment of the ropes for moving the approach trestle. The engines and incline proper are carried on a car which is run by suitable gearing, operated by the engineer.

Each conveyor consists of a wooden trestle approach, a steel framework incline mounted on trucks and the necessary machinery for hauling the loaded cars. Fig. 10 gives a very good idea of the appearance of the apparatus, except that with this one exception all the inclines are made of steel. Two of the steel inclines are shown by Fig. 11. These two illustrations give a good idea of the character of the work on the two sections under consideration. Fig. 10 shows one of the conveyors on the north side of the canal taking out the third cut. It will be noticed that the slope is finished toward the spoil bank on a horizontal axis. The diagram, Fig. 12, shows the theory of the operation of the tipple. In this diagram A B C is the trussed incline, and D E is the tipple hung on the horizontal axis at B. From the engine the hauling rope passes to the sheave M, thence to the sheave E, and thence to the car F. The car is pulled up the incline track A B, and onto the pivoted platform D E, until the front wheel strikes the buffer, L, which holds the car from going further. There being no further movement of the car possible, the pull on the rope E M tends to revolve the platform D E on the axis B. As the loaded car nearly balances the counterweights holding D E in position, only a slight pull on E M is necessary to revolve the tipple and car into the position d e f shown by the dotted lines. In this inclined position

Fig. 10. View of Incline Conveyor Working on Section M.

to the bottom of each cut as the work proceeds. Fig. 11 is an attempt to show the full width of the canal with all of the machines at work, but owing to the great width of the excavation and the slight elevation which could be obtained above the surface, the right side cut is hardly to be distinguished. The inclines indicate where the steam shovels are, however. In the foreground of this view is shown a train of tram cars which were used in connection with wheel scrapers and wagons for taking off part of the top soil. The tram car track is built a few feet west of the east boundary of Section M, and the view is therefore one looking west.

Turning now to the incline, the framework is simple and the machinery consists merely of a 10 × 16-in. double steam cylinder hoisting engine. The only parts of the conveyor which call for any particular description are the tipple and the brake system for controlling the descent of the cars. The tipple is shown in the act of dumping a car in Fig. 10. As will be seen, it is simply a portion of the track at the top of the incline, hung so as to revolve over the load slides out of the front end of the car. The pull on E M is then discontinued, and immediately the counterweights G and H act to pull the tipple back to its original position, and the car runs by gravity back down the incline. The counterweight G acts first to start the tipple and bring it into the line of action of the weight H; the weight G then strikes the floor A C, and H acts alone to bring the tipple back into position.

At no time during the operation of hauling and dumping does the engineer see the car, but he regulates all movements by a system of simple automatic signals. As the car approaches the tipple, in running up the incline the wheel flange presses a lever, which rings a bell in the engine room and warns the engineer to decrease speed, and when the tipple begins to swing over, a pointer is operated by suitable connecting wires, which indicates when the position d e has been reached and the load dumped. The engineer then releases his engine drum, and pays no further attention to the car, which is swung back by the counterweights, and begins its descent of the incline. To control the car in descending,

a lever, connected by wires with the brake to the engine drum, is placed at the foot of the trestle approach at the edge of the canal. This lever is operated by a brakeman, who can watch the car and control its speed at will, by simply setting and loosening the engine brake. As there are two independent tracks and cables, there have to be, of course, two brake systems and operators. The view, Fig. 10, shows the brakeman at the edge of the slope. Many of the details of the tipple which are shown in the diagram, Fig. 12, are also shown in this view.

From the foregoing description and the accompanying cuts, a very clear knowledge of the construction and operation of the conveyor may be obtained. The capacity of the conveyor is limited by the capacity of the shovel to handle material. From the records of the Superintendent of Construction we take the following figures of the cubic yards of material handled by each conveyor per ten-hour shift for several months. These figures are all averages of from 50 to 100 shifts.

		Section M, cu. yds.	Section L, cu. yds.
May,	1894	625	750
July,	"	900	890
August,	"	730	730
September,	"	750	810
October,	"	750	945
November,	"	702	702
December,	"	808	808
January,	1895	595	595
June	"	703	703
July,	"	752	752

On special runs the amount of material handled per hour has been considerably above any of these figures, but from 75 to 80 cu. yds. per hour is thought to be all that can be depended upon day after day in all kinds of weather. The principal advantages claimed for this system of working are simplicity and low cost of the conveying machinery, ease in handling—the conveyor can be moved to take a new cut in 35 minutes—short haul to spoil bank, small number of workmen and the working of the side slopes first, thus enabling this work to be completed during warm weather when the ground is soft, while the center core, which requires little hand labor, is taken out during the cold weather.

Fig. 11. General View of Sections M and L Looking West.

Steam shovels are used to fill the cars running on the incline, one shovel being used for each conveyor. Two of the shovels used are Barnhart's A A type, built by the Marion Steam Shovel Co., Marion, O., and two are Bucyrus shovels, built by

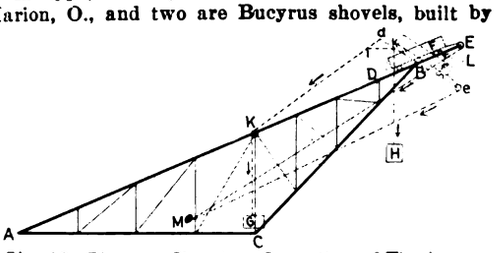


Fig. 12. Diagram Showing Operation of Tipple on Incline Conveyor.

the Bucyrus Steam Shovel & Dredge Co., South Milwaukee, Wis. Owing to the method of operating and of making the measurements, it is very

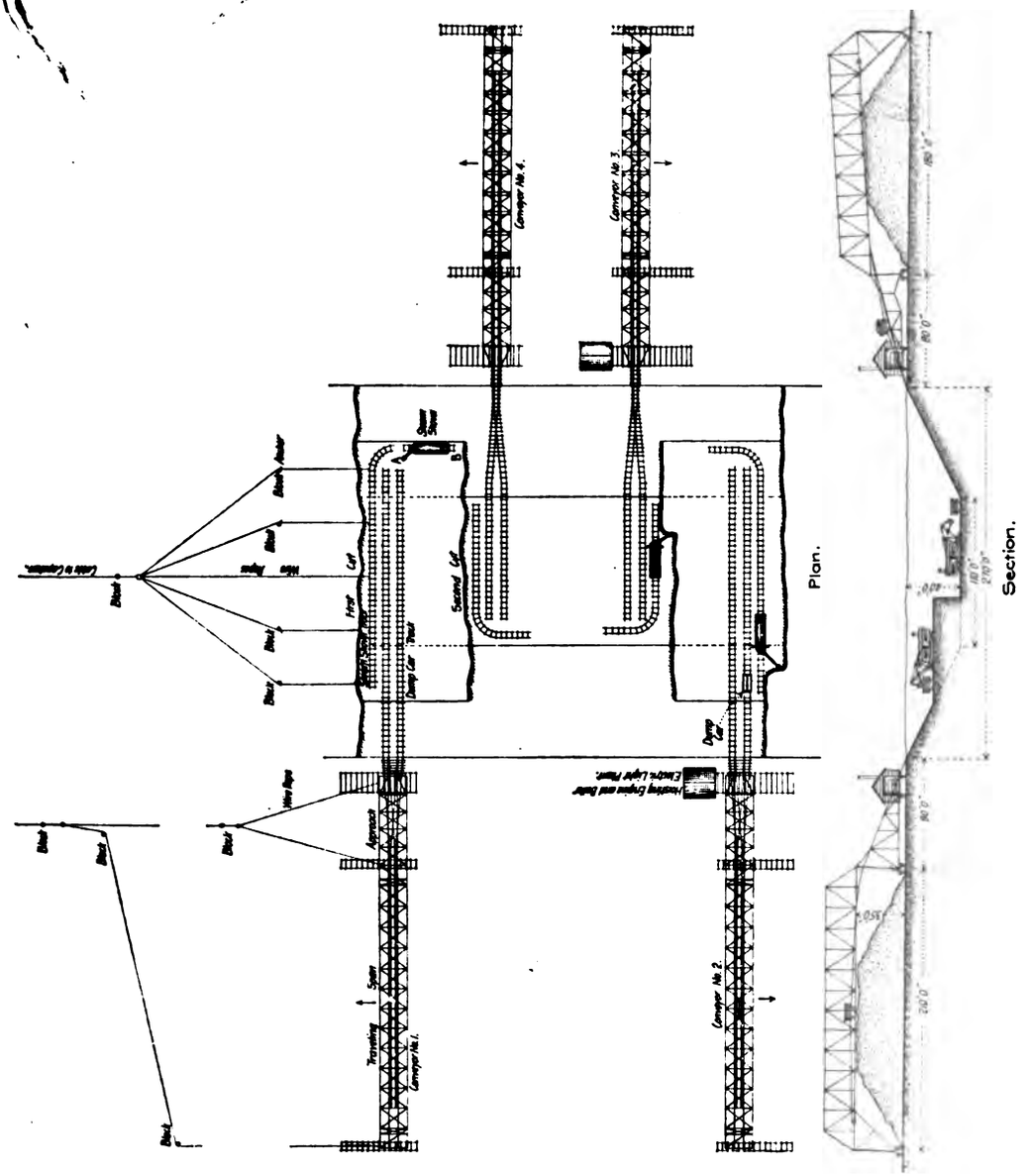


Fig. 13. General Plan and Sections Showing Arrangement of Steam Shovels and Conveyors on Sections K and I.

CHRISTIE & LOWE, Contractors, Chicago.

difficult to secure reliable records of work done by individual shovels.

The cost of the work thus far done on Sections M and L is divided as follows by the contractors: Coal, 14%; repairs, 14%; excavating, 36%; conveying, 42%. The coal account is chargeable about equally to the excavator and the conveyor. Of the 14% expended for repairs, 8% is charged to the excavator and 6% to the conveyor. This makes 48% of the total cost chargeable to excavating and 52% to conveying. These figures are averaged from an excavation of 1,200,000 cu. yds. of material.

Sections K and I.

The bridge conveyors used to handle the material on Sections K and I by the contractors, Christie & Lowe, of Chicago, Ill., were described in detail in Engineering News, Nov. 15, 1894, and will be referred to only briefly here. Fig. 13 is a general plan of the bridge conveyor plant. Conveyors 1 and 4 work east, and conveyors 2 and 3 work west. Nos.

1 and 2 taking out the top lift, and Nos. 3 and 4 the bottom lift. The arrangement of the dump car and steam shovel tracks, the power houses, etc., are so plainly indicated by the illustration that no further description is necessary.

The capacity of these bridge conveyors to handle material is limited by the capacity of the steam

Fig. 14. The New Era Grader at Work on Sections K and I.

THE F. C. AUSTIN MFG. CO., Chicago, Builders.

shovels to excavate the hard clay. According to the records of the Superintendent of Construction, the output of the plant has been as follows:

Month.	Section K. Shifts.	Cu. yds.	Section I. Shifts.	Cu. yds.
September, 1894.....	49	600	92½	555
October, "	49	660	127½	625
November, " 105¾		582	105¾	582
December, "	79	695	79	695
January, 1895.....	50½	557	50½	557
June, "	81	807	81	807
July, "	76	821	76	821

For November, December and January the reports give the total number of shifts worked on both sections, and in the table this number has been divided equally between the two sections. In December and November, 15 shifts and 12½ shifts, respectively, out of the total number of possible day shifts in the month, were lost in delays for repairs, etc. For these same two months all four conveyors worked continuously, except for delays noticed, and their aggregate output for December was 109,805 cu. yds., and for November was 123,000 cu. yds. About 34% of the total cost of excavation is chargeable to conveying.

The labor force for the bridge conveyor system is about as follows: Conveyor force, one engineer, one fireman, two men on truss; pit force, three men on shovel, five shovel tenders, 12 laborers breaking down face, trimming slopes, etc., and one foreman.

Owing to an unavoidable delay in obtaining the necessary machinery for these conveyors, and to keep up with the contract requirement as to monthly progress, 5 ft. in depth over the entire two sections was moved by teams, using wheel scrapers and New Era graders and wagons. The performance of the New Era graders proved especially satisfactory in this top-soil excavation. The construction of this machine is familiar to American engineers, and the accompanying view (Fig. 14) shows clearly the manner of operating it on the drainage channel work. From such figures as are available these graders showed an average output per 10 hours of about 500 cu. yds. Records kept on Section K during August and September, 1894, give the average output as 490 cu. yds. and 515 cu. yds. per 10 hours, respectively. On Section I the average output of each grader for September, 1894, was 485 cu. yds. per 10 hours. The total time worked on both sections was 123 10-hour days, and the average daily force was 50.4 men, 41.9 teams, 22.3 wagons and 3.1 New Era graders. The average output per

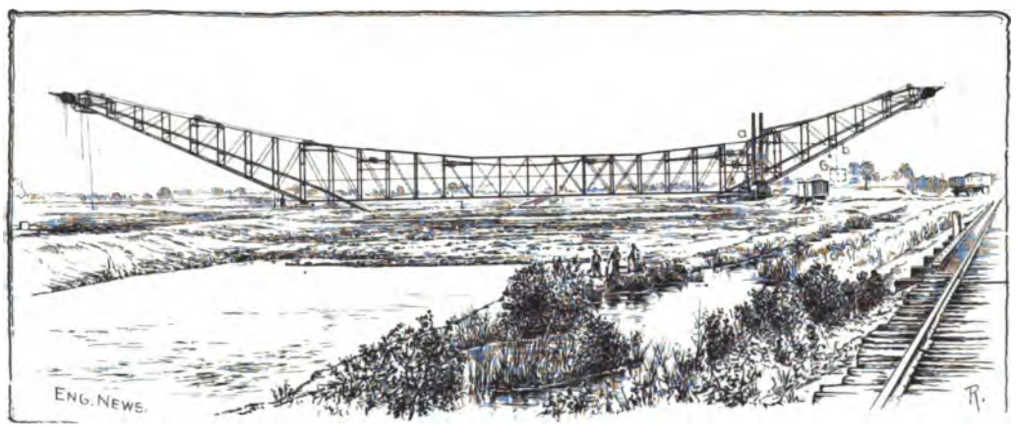


Fig. 15. Double Cantilever Conveyor on Section H.

day worked for each grader was 508 cu. yds. The material was a fairly soft, clayey loam, and the average haul was about 500 ft. On Section K about 68,300 cu. yds. were removed with wheel scrapers in 62 10-hour days, the average force

being 59.6 men, 36.8 teams, 23.9 wheel scrapers and 2 plows. The average output per 10-hour day for each wheel scraper was 46.1 cu. yds.

Sections H and G.

These two sections are much like the preceding sections in their physical characteristics, the material being a hard brick clay, somewhat sandy in places, covered with about 5 or 6 ft. of prairie loam. They were put under contract to Gahan & Byrne, of Chicago, Ill., Dec. 23, 1893, the prices for excavation being 29 cts. per cu. yd. for Section H, and 28 cts. per cu. yd. for Section G. According to the latest estimates the amounts of material to be excavated are 1,077,032 cu. yds. and 1,363,975 cu. yds., respectively, for the two sections. Like the preceding sections the channel is 110 ft. wide on the bottom, with side slopes of 2 to 1, and the spoil banks are parallel with the channel and 80 ft. distant from its edge.

Early in the spring of 1894 the contractors began to install their plant. Teams and dump cars loaded by steam shovel were first put at work on the east end of Section G, and a little later a belt conveyor was put in operation on the west end of the same section. On Section H a monster apparatus, designed by Hoover & Mason, of Kansas City, Mo., was completed late in the season of 1894, and early in 1895 two incline conveyors, much like those used on Sections M and L, were installed, one on the east end of Section H, and the other about the middle of Section G.

More or less excavation has been done by each of these plants, but up to this time the bulk of the material has been taken out by the belt conveyor and dump cars and scrapers. The reason of this is that the Hoover & Mason conveyor has been partially wrecked twice by unfortunate accidents, and the incline conveyors have been at work for a short time only. The several machines and their methods of operation will be described here, and such notes of their capacity will be given as are available.

The apparatus designed by Hoover & Mason may be called a double cantilever conveyor for want of a better name. Its general design is pretty clearly shown by Fig. 15, which is sketched from a photograph. It consists of a bridge 320 ft. long spanning the channel, with a cantilever arm at each end, extending over the spoil bank. The south cantilever arm is 148 ft. long, and the north 172 ft. long, making the total length of the structure, from tip to tip of the cantilevers, 640 ft. The whole structure is supported on cars placed at the ends of the main span. These cars run on tracks laid along the berms of the channel.

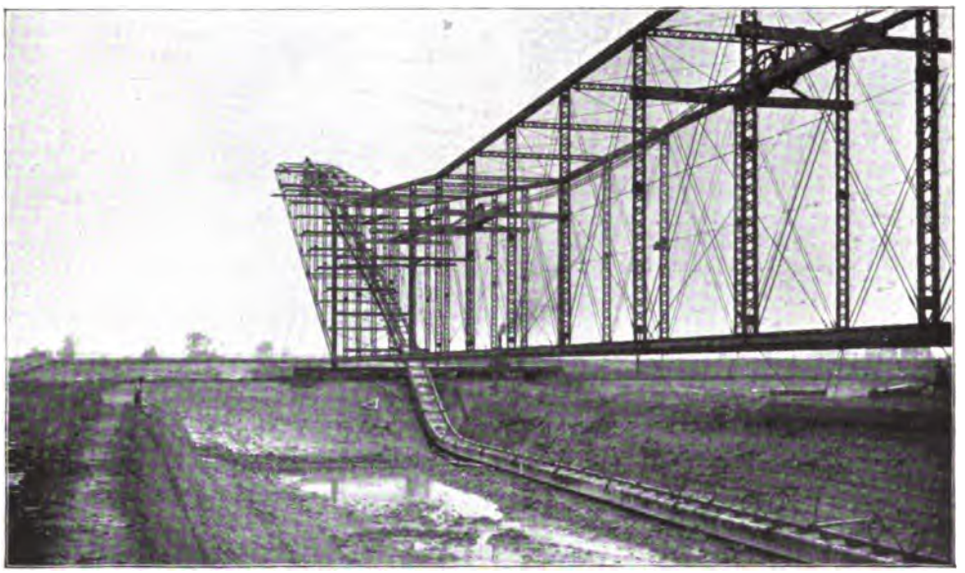


Fig. 16. Detail View of Double Cantilever Conveyor, Showing System of Excavation.

At the extremities of the cantilevers are large drums over which a steel belt, composed of a series of steel pans linked together, mounted on trunnions and traveling on a track between the trusses, is caused to pass. This belt is endless, and is propelled by suitable machinery placed on the car running along the south bank of the channel. The sag of the belt goes to the bottom of the channel, and the material is loaded into it by means of a gang of plows operated by cables and winding engines. Fig. 16 shows this arrangement quite clearly, although the pit was not sunk the full depth of the channel when the view was taken. The plows are hauled transversely across the channel, shaving down the bank against which

the belt lies. The diagram, Fig. 17, indicates the process quite clearly. Of course, as the belt or pans reach the extremity of the cantilever and pass over the drums, the earth with which they are filled falls out; the operation of the belt being, in fact, exactly like that of a bucket conveyor for handling grain or other material.

Although the diagrams in Fig. 17 explain the operation in a great degree, some of the dimensions and details of construction need to be described briefly. The pans making up the belt are 4 × 4 ft., hinged on 2-in. axles with 12-in. wheels, and are connected by eye-bars. The speed of the belt is 120 ft. per minute, and it is operated by a 14 × 17-in. engine. The plows are hauled by a 9 × 12-in. engine, and each cuts a furrow 7 ins. deep and 20 ins. wide. As the speed of travel of the plows is 200 ft. per minute, the plows should excavate 4,321 cu. yds. per 10 hours, theoretically, or, allowing for delays, breakage, etc., say, 3,000 cu. yds. per day. Just what the work of the machine has been will be noted further on.

Shortly after the completion of the conveyor in November, 1894, one of the temporary timber supports for the belt track, which was held up by a jack, failed, owing to the slipping of the jack, and the belt, loaded with dirt, sagged down onto the bottom laterals. The shock, coupled with the pull of the machinery on the deranged belt, caused the north cantilever arm to buckle and fall in a complete wreck. Work was begun at once rebuilding the ironwork, and as this was about finished, another accident wrecked the structure. During a severe gale on Jan. 21, 1895, the conveyor, which had not been anchored securely, was blown along the tracks until the leading trucks fell off the ends of the rails, overturning the whole structure. Both cantilevers were wrecked, but the main truss was but little injured. Again the work of rebuilding was begun, but this time it was decided to leave off the south or shorter cantilever arm. Accordingly a tie was run from a to b (Fig. 15), and a heavy counterweight, G, suspended at b, the remainder of the ironwork being removed. With the exception of the modifications required by this change, the machinery, pans, drums, etc., are exactly as they were in the original structure. As the conveyor cost $32,000 originally, it will be readily understood that considerable confidence and courage were required on the part of the contractors to rebuild it twice, although, of course, the cost of rebuilding was far less than the first cost of the work. On the whole, the conveyor is probably the most elaborate and costly device on the entire channel, besides being the widest departure from ordinary methods of excavation.

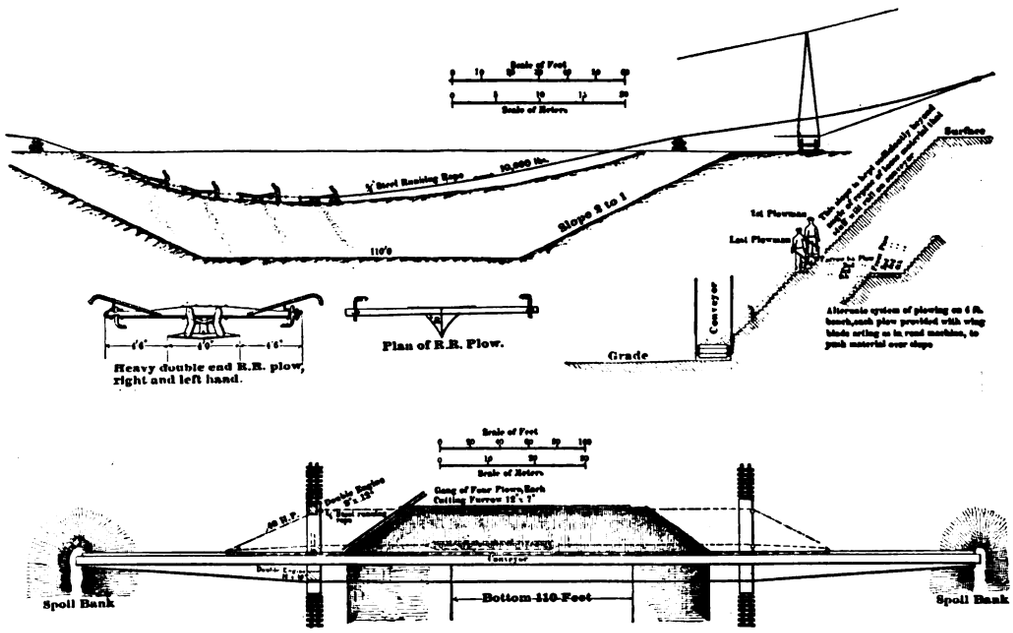


Fig. 17. Diagram Showing Operation of Double Cantilever Conveyor. Section H.

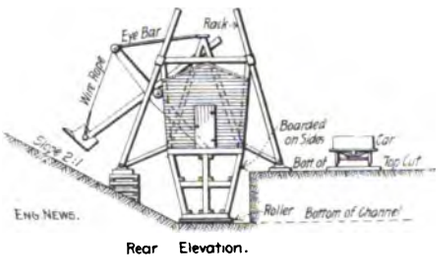
Owing to the accidents just described, little excavation has been done by the conveyor. Just before the first accident, and before the plows had been got into good working order, 940 cu. yds. per ten-hour day were being taken out. The designers express their confidence that over three times this amount can be handled with everything in good working order. Later experience did not bear out the claims of the builders. In July, 1895, the conveyor worked 45 10-hour shifts and handled only 499 cu. yds. per shift.

The belt conveyor referred to above has been

worked on Section G, taking off the top cut of about 12 ft. This apparatus was designed by Mr. Lindon W. Bates, of Chicago, Ill., and is simply an endless rubber belt, 22 ins. wide, running transversely across the channel and over the spoil bank. Along the bottom of the channel and up the slope the belt is guided by a wooden frame with suitable rollers, and over the spoil bank it runs on a steel truss as is clearly shown by Fig. 18. The belt is operated by an engine placed on a car traveling along the berm about 40 ft. from the edge of the channel. A steam shovel loading into a granulator supplies the dirt to the belt, and a metal scraper placed on the truss sweeps it off onto the spoil bank. The granulator is similar to those used in brick yards, and, as the name signifies, is used to pulverize the earth coming from the steam shovel, so that it can be easily conveyed by the belt. It is mounted on a car which travels transversely across the canal as the excavation advances. When the shovel has completed a cut clear across the channel, the truss, which is mounted on cars, the belt frame, granulator and steam shovel tracks, etc., are moved toward the face and a new cut made. In this manner the whole apparatus travels along the channel, taking out a cut about 12 ft. deep the full width.

The force worked on this plant is generally about 35 men, about half of whom come under the head of skilled laborers and receive wages of from $2 to $3 per day. In this respect the belt conveyor system is at a disadvantage when compared with the incline or bridge-conveyor systems. Besides this skilled labor there is also the disadvantage of having three separate and independent sets of power machinery—viz., the steam shovel, granulator and belt engine, to get out of order and wear out.

Fig. 18. Bates' Belt Conveyor on Section G.



Rear Elevation.

Fig. 19. Sketch of Trenching Machine Used on Section G.

In the illustration, Fig. 18, the belt is shown running across the bottom of the channel, up the slope and over the truss, while in the left foreground is the steam shovel with the granulator just beyond. Detail drawings of the whole apparatus were published in Engineering News, Sept. 20, 1894, which may be studied by those desiring more exact information.

The capacity of the belt conveyor to excavate the hard clay in which it is working is from 300 cu. yds. to 800 cu. yds. per ten-hour day, depending upon the weather, breakdowns of machinery, etc. The exact record of work taken from the reports of the Superintendent of Construction for several months is as follows:

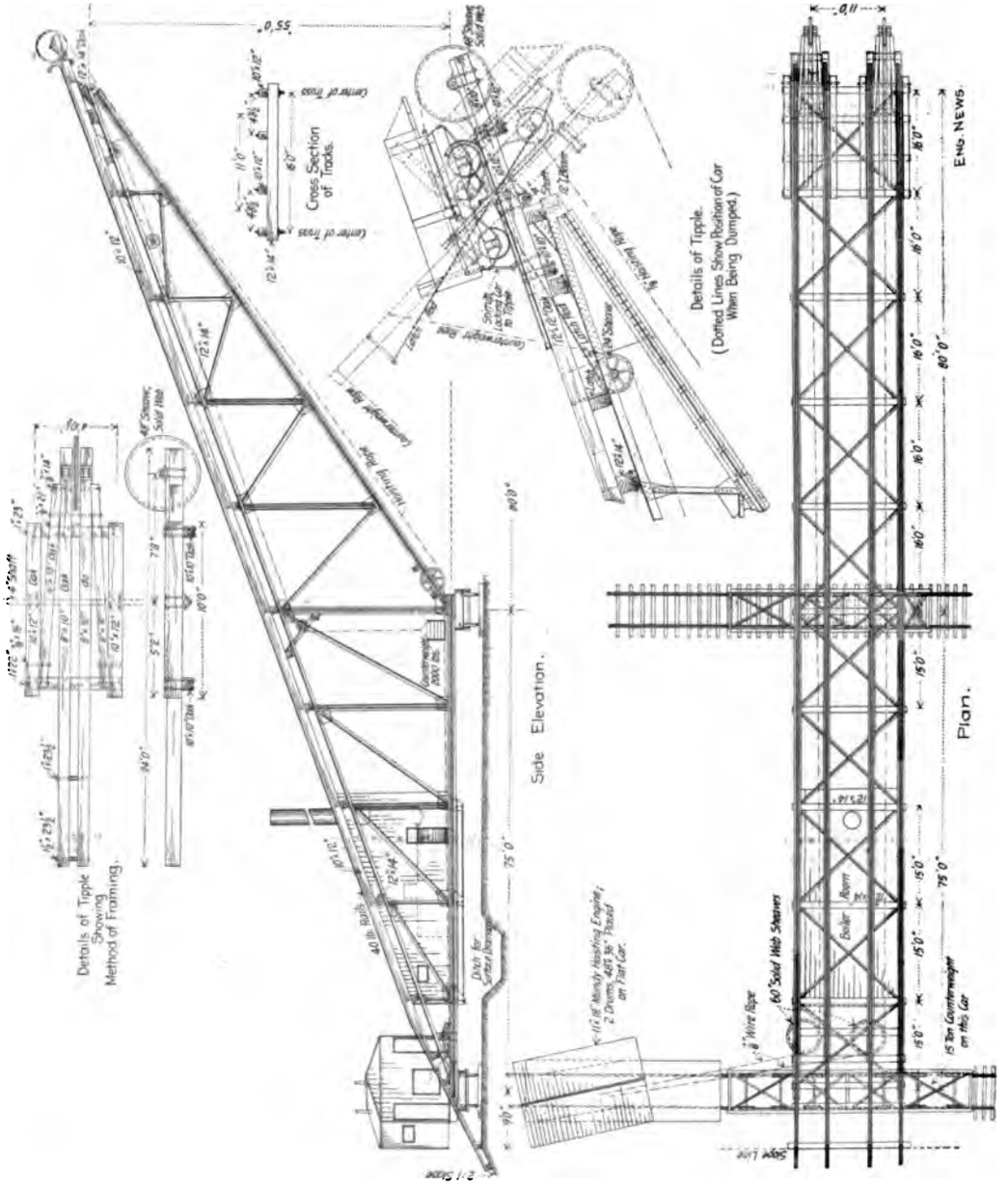

Cross Section of Tracks.
Details of Tipple. (Dotted Lines Show Position of Car When Being Dumped.)
Side Elevation.
Plan.
Details of Tipple Showing Method of Framing.
END NEWS.

Fig. 20. General Details of Incline Conveyors on Sections H and G.

Month.		Ten-hour shift.	Cu. yds. per shift.
September,	1894	..	419
October,	"	23	777½
November,	"	..	651
December,	"	20	313
May,	1895	..	520
June,	"	50	513
July,	"	41½	548

These figures, it must be understood, represent pit measurements, and are per day worked, and not per working day. For example, in the month of September the conveyor handled 419 cu. yds per day worked, and only 318 cu. yds. per working day. The steam shovel (a Victor, Class No. 1) is limited by the capacity of the belt to handle the dirt here, instead of being the limiting factor itself, as is the case with the bridge conveyors on Sections K and I and the inclines on Sections M and L. Rainy weather and snow are especially bad for the belt, the moisture causing it to slip and clog.

The steam shovel and dump car plant working on the east end of Section G call for little mention. Peteler cars of 1 cu. yd. capacity, hauled by teams are used. During the months of September, November and December, 1894, the amounts of materials excavated per shovel ten-hour shift were 662 cu. yds., 920 cu. yds. and 841½ cu. yds., respectively. As with the belt conveyor, the amount of material handled per day worked was greater than the amount handled per working day. In September the respective figures were 662 cu. yds. and 556 cu. yds. The steam shovel and tram car plant has worked on the upper lift only. To take out the lower lift one of the incline conveyors is used.

Before describing this incline conveyor, brief mention may be made of a trenching machine used on Section G. In making a transverse cut across the channel with a steam shovel, there always remains a triangular mass of earth at each end to cut out by hand. This is necessary in order to preserve the slope. The trenching machine was designed to take out this slope cut by digging a trench along the channel, as shown by Fig. 19, which is a part transverse section of the channel showing a rear elevation of the trenching machine. As will be seen, the trenching machine is simply a modification of a steam shovel, so arranged that the slope can be cut out by the dipper. The operation of the machine is evident from the sketch.

The incline conveyors, two of which are used, were designed by Mr. J. W. Page, the engineer for the contractors. Fig. 20 shows the construction of one of these inclines, and Fig. 21 is a view of the same device reproduced from a photograph. As will be seen, the machine has tipples at its upper end, which revolve on a horizontal axis and dump the cars just as do the tipples used on Sections M and L. The location and operation of the boiler room, engine house and hoisting ropes are indicated in Fig. 20. In the pit the method of operation is similar to that on Sections K and I. Instead of taking a longitudinal cut along the channel, as is done on Sections M and L, the tracks run down the slope and across the bottom of the channel, and the steam shovel makes a transverse cut, as is done on Sections K and I. In brief, the conveyor system of Sections M and L is combined with the system of excavation used on Sections K and I.

Detailed figures of the outputs of these inclines began to be secured in May, 1895, and show the following results:

Month.	Ten-hr. shifts. Sec. H.	Ten-hr. shifts. Sec. G.	Cu. yds. per shift. Sec. H.	Cu. yds. per shift. Sec. G.
May, 1895	..	..	..	528
June, "	47	47	509	631
July, "	51½	45½	791	636

The foregoing description indicates pretty clearly the methods of work on Sections G and H. To sum up briefly, however, the top soil, to a depth of from 4 ft. to 6 ft. over both sections, has been removed by teams, scrapers, etc.; on Section G the top cut is being made by the dump car and steam shovel plant and by the belt conveyor, and the bottom cut is being made by one of the incline conveyors; and on Section H the other incline conveyor and the double cantilever conveyor are used.

Fig. 21. Steel Incline and Tipple for Incline Conveyors, Sections H and G.

CHAPTER V.

THE WILLOW SPRINGS DIVISION.

HE Willow Springs Division of the Drainage Channel begins at the east end of Section F and extends to the west end of Section 1, a distance of about 7¼ miles. Beginning at the east end of Section F the channel is 110 ft. wide at the bottom to a point within 500 ft. of the west end of the same section, where it widens out to the normal section 202 ft. wide on the bottom, and continues this width to the east end of Section 1, where the rock channel, 160 ft. wide at the bottom, begins. The side slopes are 2 ft. horizontal to 1 ft. vertical. The first of the river diversion channel work occurs on this division. The engineer of the division is Mr. H. B. Alexander, whose offices are located at Willow Springs, Ill. We are indebted to Mr. Alexander for much aid in securing the matter for the articles on Sections F to 1, inclusive.

Section F.

This section is particularly notable as involving the first work of river diversion, and also as being the first section yet described which has been taken from the original contractors and relet. The original contract for the section was signed by Ricker, Lee & Co., of Galveston, Tex., Nov. 23, 1892, and called for the removal of 1,399,495 cu. yds. of glacial drift, and 45,900 cu. yds. of solid rock at 23¾ cts. and 80 cts. pr cu. yd., respectively. Later estimates (Jan. 1, 1895), based on more accurate data, reduced the quantities on the section to 1,251,887 cu. yds. of glacial drift and 16,724 cu. yds. of solid rock. About 70,000 cu. yds. of the glacial drift excavation was on the river diversion channel.

The contractors began work promptly after signing the contract, and on Jan. 1, 1894, were considerably ahead of the contract requirements in the amount of excavation completed. On April 3, 1894, however, they notified the Board of Trustees that a very hard material had been encountered in the glacial drift work, which could not be excavated at the price they were receiving—viz., 23¾ cts. per cu. yd.—and asked that a readjustment of the price be made for this hard material. The argument made by the contractors in support of their request was that the borings made by the engineers to determine the character of the material failed to indicate in any way the presence of this hard material, and were thus misleading.

Similar complaints having been made by the contractors working the succeeding Sections E, D and C, the Board of Trustees appointed a special committee of adjustment to consider the question of the claim for hard material on the four sections named. As the investigations and decisions of this committee apply to Sections E, D and C, which will be described in future articles, as well as to Section F, now under consideration, and because they established the policy of the Board of Trustees in future disputes of similar nature, they are given here in some detail. It should be stated that in the very beginning the claims of the contractors for Sections D and C were set aside, so that in reality the following discussion refers only to Sections F and E.

The investigations of the committee consisted in sinking a series of 6 × 6-ft. test pits at intervals along the sections in dispute, the investigation and report of a commission of seven engineers from the engineer corps of the Drainage District, and the testimony of a number of well-known contractors. The test pits which were sunk, in the words of the Chief Engineer's report, "disclosed the fact that the material to be excavated was of a more difficult character than was indicated by the simple borings." They also disclosed the existence of a large amount of a peculiar quicksand underlying the hard material. The commission of engineers was divided in its opinion. Four members, including the Chief Engineer, agreed that an increase in price to 41 cts. per cu. yd. for the material remaining on both sections would be a just valuation of the work, and two members, including the Assistant Chief Engineer held that there should be no increase in price for Section E, but considered that an increase of 6¼ cts. per cu. yd. might be justly allowed on Section F. Some of the engineers also suggested that the quicksand which had been shown by the test pits could perhaps be handled by hydraulic dredges. The advice of a committee of contractors was secured to consider this question of dredging, and its opinion was in substance that dredging would not work satisfactorily, and perhaps not at all. The question of handling this quicksand, however, assumed no importance, as the contractors on both Section F and Section E agreed to take their chances with it, providing the prices for hard material be raised to 50 cts. and 53 cts. per cu. yd., respectively, on these sections.

The committee of adjustment was divided in its

opinion as to what action to pursue in the face of the testimony, but finally presented a majority and a minority report. The majority report recommended that no increase in price for hard material be allowed, and this report was adopted and acted upon by the Board of Trustees. The argument of the majority report seems to have been that any action granting relief would be a precedent which would involve serious annoyance from other contractors who might encounter material a little harder than they had anticipated, and claim an adjustment of prices. It was also considered reasonable to suppose that the contractors should have allowed for contingencies of this character in making their bids, and if by a mistake in judgment they had not made sufficient allowance, the Drainage District should not be expected to stand the loss.

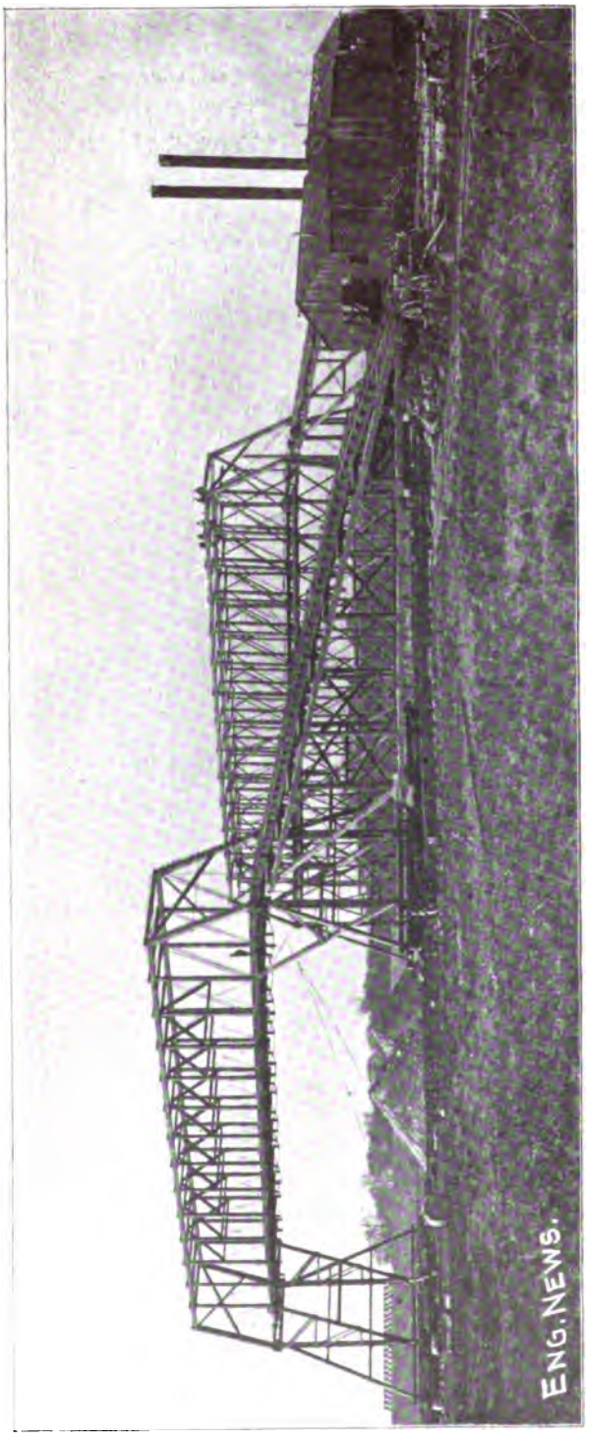


Fig. 22. Bridge Conveyors Used on Section F.
WEIR & McKECHNEY, Chicago, Contractors.

The minority report, on the other hand, held that the early completion of the canal was paramount to questions of precedent, and that where grievous hardship devolved on the contractor on account of errors to which the Board of Trustees was a party, they were bound to do what equity might require. The test pits proved that the small borings had not indicated the true character of the material, and to declare the contract forfeited and relet the section to new contractors would take at least six months. For these reasons the minority report recommended that relief be afforded to the contractors by placing the price of the hard material at 50 cts. per cu. yd., so that work might be continued without interruption.

Although failing to receive the relief they expected, the contractors for Section F prosecuted work until the early part of the month of November, 1894. During that month the Chief Engineer reported the work delinquent, and later the section was ordered relet to new contractors. In January, 1895, the new contract was let to Weir & McKechney, of Cincinnati, O., at 29½ cts. per cu. yd. for glacial drift and 90 cts. per cu. yd. for solid rock. As the first contractors had excavated 662,527 cu. yds. of glacial drift, there remained 589,360 cu. yds. of glacial drift and 16,724 cu. yds. of solid rock for the new contractors to take out. The work of the two firms of contractors is taken up in the order of their contracts in the following paragraphs.

Before describing the methods of excavation adopted, it is im-

portant to get a clear understanding of the character of the material. The top soil is the usual soft prairie loam, which becomes more and more clayey in character as the depth below the surface increases. Underlying this is a stratum of very hard "indurated clay." This layer of clay constitutes the bulk of the intractable material about which the difficulty just described arose. In order to dig it with any degree of success, blasting is necessary, and owing to the toughness as well as the hardness of the clay, the explosive, instead of shattering it, tears it out in large blocks, which often have to be broken with small blasts before they can be handled. Coupled with the hardness of the material is the annoyance of frequent boulders, which are scattered through and firmly imbedded in the clay. Below the clay are beds of the peculiar quick-acting sand previously noted. This sand is so soft that a person quickly sinks into it, and is also somewhat viscid; thrusting against it with the foot causes it to shake, jelly-like, for a considerable distance around the point of pressure. Owing to this peculiar action, the sand has been given the name of "bull liver." If the hand is thrust into this "bull liver" and withdrawn the material clings to the fingers in long, stringy masses. The material was successfully excavated after draining away the entrained water.

The first contractors, Ricker, Lee & Co., began work by excavating the first 5 or 6 ft. in depth over the whole section with wheel scrapers. Steam shovels were then put at work in a cut about 12 ft. to 14 ft. deep, running lengthwise of the section. Four trains of Thacher dump cars were used to convey the excavated material to the spoil bank, two trains for each shovel. One locomotive for each shovel was used to place the cars, and the other to haul the trains to and from the spoil bank. The Thacher dump car used is deserving of mention in one or two particulars, principally on account of the dumping mechanism. Each car is provided with an air cylinder, the piston of which when forced out dumps the car. These cylinders are connected with the air pump on the engine in a manner somewhat similar to the well-known air-brake, and just as the engineman can apply the air-brakes in ordinary train service, he can dump the Thacher cars from the engine.

Bucyrus steam shovels were used, and, as indicated above, when working in the indurated clay had to have the material blasted in front of them. Dynamite and black or Judson powder were used as explosives, and the holes drilled from 16 ft. to 18 ft. deep. On an average 14 men were employed in drilling and blasting, working Sundays and generally five nights in the week. With the material blasted, the shovels handled about 350 cu. yds. per 10-hour shift, when working.

The system of excavation adopted by the present contractors, Weir & McKechney, is practically identical to the one used on Sections K and I. A cut is made transversely across the channel by a steam shovel, which loads into dump cars. The cars are hauled across the bottom of the channel, up the slope, and onto a bridge which spans the spoil bank, and are then dumped through the open floor of the bridge. Instead, however, of a berm of 80 ft. between the channel and spoil bank, as is the case on Sections K and I, there is here a berm of several hundred feet, with a corresponding increased length of haul. Two bridges or conveyors are used, both starting near the middle of the section, and one working each way towards the ends. Fig. 22 is a view of the bridges taken before the falsework for erection had been removed from under one of them. Both spans are combination wood and iron, and are 210 ft. long. The cars are hauled by cable, the winding engines being placed in the houses shown near the foot of the trestle incline. The houses, inclines and trusses are mounted on trucks so that they can be moved along the track as the work proceeds.

In July, 1895, one of the conveyor spans was wrecked by accident, and this delayed work on the section considerably. The following figures show the output of each conveyor worked for five months:

Month.	No. 10-hr. shifts.	Cu. yds. exc. per shift.
May, 1895	64.9	162
June, "	73	318
July, "	66	341
Aug., "	54	546
Sept., "	85	539

Barnhart's AA type of steam shovels, manufactured by the Marion Steam Shovel Co., of Marion, O., are used to load the cars.

Section E.

Similarly to Section F, this section has been taken from the original contractors and relet to others, as the result of the dispute already referred to as arising over the prices for hard material. The various phases of this dispute outlined in the description of Section F occurred in connection with Section E, and the final decision of the Board of Trustees was the same. The original contract for Section E was let to Streeter & Kenefick, Feb. 1, 1893, and called for the excavation of 1,840,773 cu. yds. of glacial drift, 67,465 cu. yds. of which were in the river diversion channel, and 5,000 cu. yds. of solid rock. The latest revised estimates give the amount of excavation on the section as 1,887,993 cu. yds. of glacial drift and 78,765 cu. yds. of solid rock. The prices for excavation were 27½ cts. per cu. yd. for glacial drift and $1 per cu. yd. for solid rock. The contract was taken from Streeter & Kenefick, Aug. 29, 1894, and relet to Angus & Gindele, Sept. 19, 1894, at 27 cts. per cu. yd. for glacial drift, and 80 cts. per cu. yd. for solid rock. This bid was the lowest of all received, and, it is to be noted, was ½ ct. per cu. yd. lower on glacial drift, and 20 cts. per cu. yd. lower on solid rock than the original price.

The first contractors, Streeter & Kenefick, began work soon after being awarded the contract, and on Jan. 1, 1894, were considerably ahead of the contract requirements for the amount of material excavated. Practically the same system of steam shovels and spoil trains was used to handle the hard material as has just been described for Section

F, and the soft top soil to a depth of from 3 ft. to 8 ft. was removed by wheel scrapers. Altogether about 469,000 cu. yds. were taken out by this method, the work being divided into five sections, each of which was worked by a separate outfit. According to records obtained by Division Engineer Mr. E. R. Shnable, the output per wheel scraper averaged as follows:

Sec.	Ave. fill, ft.	Ave. cut, ft.	Total lift, ft.	Ave. haul, ft.	Total cu. yds. exc.	Cu. yds. exc. per --10-hr. shift.-- Per team.	Per scraper.
1	12	8	20	400	94,879	29.8	42.2
2	12	8.3	20.3	400	98,515	27.1	39.3
3	11	7	18	400	85,761	24.4	35.2
4	7	3.4	10.4	400	33,185	35	50.1
5	7	4.3	11.3	400	29,678	28.3	42.1

The excavation on Section 1, 2 and 3 was in a very stiff blue and yellow clay, with a few large boulders, and on sections 2 and 5 it was a stiff, yellow clay, containing a great number of boulders of all sizes.

Angus & Gindele, the second contractors, also adopted the same system of steam shovels and spoil trains. Fig. 23 shows the arrangement of tracks adopted by them on the west half of the section. This plan was made from sketches made in April, 1895. As the steam shovel cut proceeds east, the track will be advanced, and ultimately there will be an incline connecting the tracks in the pit with those on the spoil bank at the east end of the section. Barnhart's AA type shovels are used to load the cars, the material being blasted ahead of the shovels. In addition to these shovels a large excavator, also built by the Marion Steam Shovel Co., Marion, O., was installed early in 1895. This excavator is a very large steam shovel built of wood and iron. An idea of its size may be gained from the following dimensions:

Weight	250,000 lbs.
Length of car	50 ft.
Width of car	23 "
Gage of car	25 "
Length of boom	55 "
Length of dipper handle	34 "
Size of engines	10 × 12 ins.
Size of boiler (locomotive type)	56 ins. × 20 ft.
Size of dipper	2 cu. yds.

In June, 1895, this shovel worked 35 10-hour shifts, averaging 546 cu. yds. per shift, and in August, 1895, it worked 40 10-hour shifts, averaging 700 cu. yds. per shift. On Aug. 20 the machine was destroyed by fire. Despite the size and weight of this shovel, it did little better work than the ordinary-size steam shovels used on this section, as will be seen from the figures given further on. This result seems to have been largely due to its slow action, the size of the dipper not being large enough to counterbalance the slower movement. From study of the machine at work it seems probable that by strengthening the machinery and framework sufficiently to allow of the use of a 4 or 5-cu. yd. dipper, it would prove economical, as compared with the ordinary steam shovels.

The small steam shovels used on the section were the Barnhart's AA type, and their outputs for seven months were as follows:

Month.		No. 10-hr. shifts.	Cu. yds. per shift.
December,	1894	..	403
January,	1895	61	242
May,	"	59	606¼
June,	"	63	578½
July,	"	93	562
August.	"	67	616
September,	"	67	560

Section D.

The contract for this section was awarded to E. D. Smith & Co., Nov. 23, 1892, at 26.437 cts. per cu. yd. for glacial drift. When this contract was awarded it was supposed that the material was entirely glacial drift, but the work of excavation showed that underlying the glacial drift was a very considerable amount of solid rock. This rock was first encountered in November, 1894, and, according to the latest estimates, amounts to 137,694 cu. yds. The glacial drift excavation amounts to 1,877,251 cu. yds. No price has been definitely decided upon for the rock work, but in their estimates the engineers of the Sanitary District have allowed $1 per cu. yd.

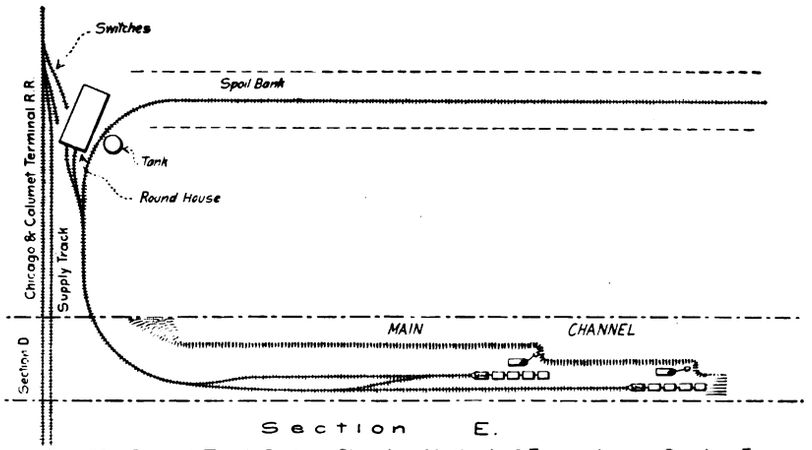


Fig. 23. Plan of Track System Showing Method of Excavation on Section E.
ANGUS & GINDELE, Chicago, Contractors.

The character of the glacial drift on Section D is similar to that on Sections F and E, but somewhat softer. In fact, like the contractors on those sections, the contractors for Section D made claims for a readjustment of price for taking out the hard material, but this claim was not allowed by the Board of Trustees, and work was continued without interruption by the contractors. From the beginning the section has been distinguished by the was 1,123 cu. yds. Unusually good work has been done on this section by the scrapers, teams and New Era graders. In August and September a force of three graders and about 50 teams, working scrapers and wagons took out 42,338 cu. yds., and 37,745 cu. yds., respectively. The contractors state that taking all work together, about 40% of the total cost of labor is chargeable to excavation, as distinguished from conveying the spoil from the pit.

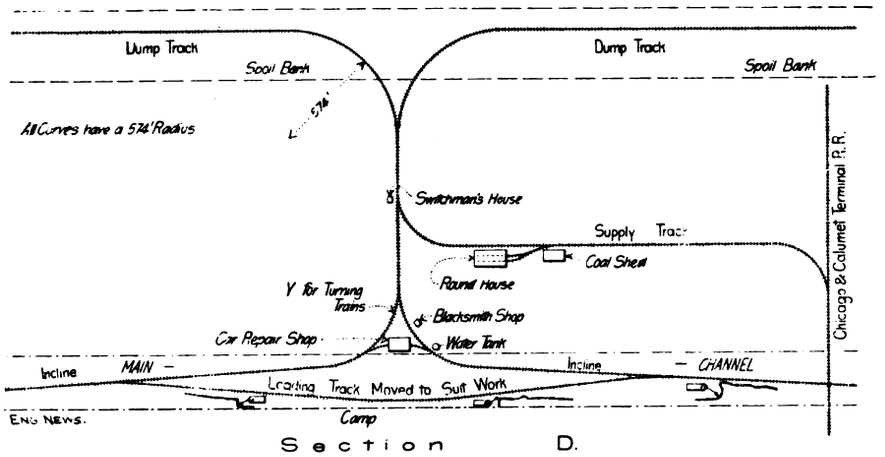


Fig. 24. Plan of Track System Showing Method of Excavation on Section D.
E. D. SMITH & Co., Romeoville, Ill, Contractors.

vigor and good management with which the work has been prosecuted.

Wheel scrapers and New Era graders and wagons were used to take off the top soil, and steam shovels loading into dump cars hauled by locomotives for removing the hard material underneath. Fig. 24 is a plan of the track system used for the steam shovel work, which shows very clearly the method of operation. The steam shovels are of the Bucyrus Steam Shovel & Dredge Co.'s make, and some records of the work done by them are given in the following table:

Month.		10-hour shifts.	Cu. yds. per shift.
September,	1894	..	1,221
October	"	..	743
November,	"	46	338
December,	"	..	823[1]
December,	"	20	504[2]
January,	1895	..	427
May,	"	113	575
June,	"	117	517
July,	"	108	566
August,	"	117	514
September,	"	101	472

[1] Loading into cars. [2] Loading into wagons.

For every month in the above table, except December, the figures given are the average output of two shovels. In December two shovels were worked loading cars as usual, one shovel loading wagons. In September one shovel of the Bucyrus No. 0 Boom type and one "Special Contractors" shovel were worked, making the excellent average per day worked shown in the table. The average of the same shovels per working day per shovel

Section C.

At about the middle of this section the main drainage channel enters the bed of the Desplaines River, which cuts across the route in an oblique direction, and follows it through the remainder of Section C, the whole of Section B and most of Section A. This necessitated the river diversion channel, which had been discontinued at the end of Section E, being resumed and continued through the three sections named. Not only was the excavation of a diversion channel necessitated on Section C, but, owing to the location of the main channel, it had to be excavated before any work could be done on the main channel. In the very beginning, therefore, attention was directed toward opening the river diversion channel at the earliest possible moment.

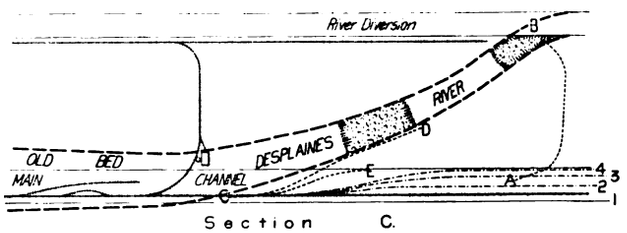


Fig. 25. Plan of Track System Showing Method of Excavation on Section C.
WESTERN DREDGING & IMPOVEMENT Co., Summit, Ill., Contractors.

The contract awarding the work to the Western Dredging & Improvement Co., of Chicago, Ill., was ratified by the Board of Trustees Feb. 1, 1893, and, according to its terms, the river diversion work was to be completed Dec. 1, 1893. Fig. 25 shows the relative location of the old Desplaines River bed, the new diversion channel and the main channel. Steam shovels loading into cars hauled up inclines, and scrapers and wagons, were used in excavating the river diversion channel. After completing the diversion channel a steam shovel was located at A, a track run from A to B, and the old river bed filled at B. Another shovel was located at E, and the material switched back to C and then run out to D, filling in the old river bed as shown.

This filling of the old river bed being completed, the tracks were arranged very much as is shown by the full lines. The track C 1 is swung across the channel into positions 2, 3, 4, etc., as the work progresses, while on the left hand the first cut is taken along the track C F, and the succeeding cuts by means of the switch F G. In addition to the steam shovels and dump cars hauled by locomotives, wagons, scrapers and wheelbarrow gangs were worked, taking out the soft muck of the old river bed, and at the west end of the section a hydraulic dredge was used for some time in the soft muck excavation.

This dredge was somewhat of a departure from the type of hydraulic dredge commonly used in this country. Instead of a revolving cutter for loosening the muck, a series of water jets was used. These jets were directed by hand, by means of long poles to which the nozzles were fastened, and were furnished with water by a pumping engine placed near the front end of the barge. To take away the loosened material, a centrifugal pump, provided with a suction pipe, similar to those used on the ordinary hydraulic dredge, was used. This machine failed to give satisfactory results, although various changes and modifications were made from time to time. The water jets loosened the muck well enough, but in doing so it appeared to scatter it through the water so much that the pump could not suck it up in paying quantities. Various attempts were made to confine the material with canvas and by other methods, but never were made to work successfully.

The dredge was completed about June 1, and in August records of its work were begun. These show the following results:

Month.	Ten-hour shifts.	Cu. yds. per shift.
August, 1894	...	289
September, "	46	320
October, "	...	311
November, "	21	196

The accompanying illustration, Fig. 26, is a view of the dredge at work. At the right hand, or forward end, of the barge are shown the men directing the water jets with long poles.

The two steam shovels used are of the Barnhart style, AA pattern, built by the Marion Steam Shovel Co., Marion, O., and their average outputs per 10-hour shift worked for eight months were as follows:

Fig. 26. Water Jet Hydraulic Dredge for Excavating Muck on Section C.

Month.	Ten-hour shifts.	Per shovel. Cu. yds. per shift.
August, 1894	...	493
September, "	15*	820
October, "	...	493
November, "	73	503
December, "	...	538
May, 1895	113	424.5
June, "	133	473
July, "	124	375

*Channel flooded by break in cross levee on Section B and work stopped, except for a few days.

In 1894 two shovels and in 1895 four shovels were used. Generally two of the four shovels have loaded into large cars hauled by locomotives, and two into small cars hauled up cable inclines. The following figures give some indication of the capacity of the two systems, although it must be borne in mind that the records cover too limited an output to be a very reliable basis for broad conclusions:

Shovel.	No. 10-hr. shifts.	Cu. yds. per shift.
No. 10	16	176*
No. 140	22	539*
No. 301	36	453**
No. 339	39	530**

* Small cars and incline hoists.
** Large cars and locomotives.

The total amount of excavation on Section C, according to the latest revised estimates, is 2,063,653 cu. yds., and the price per yard is 23½ cts. In the muck work, a prism considerably wider than the normal channel section had to be excavated in order to allow the construction of a revetment of hard material along the sides. The regular price was allowed for this extra excavation, but nothing was allowed for placing the revetment. Of course, the extra excavation was limited, the limit being a width beyond that of the normal section equal to five times the depth of the muck above the hard material, providing hard material was not encountered before this width was reached.

Fig. 27. View of Section A, Showing Levee of Discharge Basin and Hydraulic Dredge.

HELDMAIER & NEU, Mt. Forest, Ill., Contractors.

Sections B and A.

The route of the main drainage channel, which intersected the channel of the Desplaines River on Section C continues in the bed of that stream entirely through Section B and for the greater part of Section A, and the method of work adopted is to excavate the soft material with hydraulic dredges, and then unwater the sections and use steam shovels and other methods of dry excavation for the hard material. The revised estimates give for section B 1,789,038 cu. yds. of glacial drift at 27 cts. per cu. yd., and for Section A 1,789,038 cu. yds. of glacial drift at 30⅝ cts. per cu. yd., and 4,188 cu. yds. of solid rock at 80 cts. per cu. yd., making the total cost of the two sections, including subsidiary works, $1,398,859. The original contractors were L. D. Connor & Co., who signed the contract in February, 1893, but on Oct. 25, 1893, the senior member of the firm assigned the work to his partners, who continued it under the firm name of Heldmaier & Neu.

Before any work could be done on the main channel it was necessary to complete the river diversion channel, and accordingly excavation was first begun here. Nothing beyond the ordinary was encountered in this work, but when it came to constructing the levee between the river diversion and main channels, it was found that for practically the whole length of Section A it must be done through a marsh having a depth of from 10 ft. to 20 ft. of soft muck. Hard material for this levee could be secured from the main channel on Sections A and B only by long hauls and for a limited distance, and, in view of the large volume of material required, it was decided to construct a pile trestle along the line of the proposed levee, and fill it in with earth from Section 1, and also from such parts of Sections A and B as it could be obtained. This trestle was built in the fall of 1893, and the work of filling was prosecuted more or less vigorously through nearly the whole of 1894, being completed in the autumn of that year.

Meanwhile, in October, 1893, two hydraulic dredges were put in operation on the main channel. The method of operation has been to take out a prism of the soft muck enough wider than the normal channel section to allow the construction of a hard material revetment on each side. In fact, the stipulations for this character of work on A and B were exactly as already described for Section C.

The two dredges were practically alike, except in minor details, consisting of a substantially-built flat-

bottomed barge, carrying the necessary pumping and cutting machinery. From the front end of this barge a ladder, hinged at its upper end to swing up and down in a vertical plane, extends down into the water and supports the suction pipe of a centrifugal pump. This suction pipe has a vertical telescopic joint at its upper end, and a revolving cutter of steel at its lower end. The office of this cutter is merely to attack and loosen the material in its path, so that the pump can act on it. It is operated by an independent engine. From the centrifugal pump the discharge pipe, supported by a line of barges, extends to the discharge basin. At the rear end of the barge is a vertical spud, which, when the dredge is working, is driven down into the soft bottom. On this spud, as a pivot, the barge is swung back and forth by means of ropes attached to the opposite banks of the stream. The cutter thus has a vertical movement and a horizontal swinging movement, and, as it rotates in a single direction only, makes an undercut on its forward swing and an overcut back, gradually cutting a swath, so to speak, through the soft muck. The swinging ropes, spuds and all other mechanism are operated by power. Detail drawings of one of these dredges were published in Engineering News of Sept. 6, 1894.

The soft muck on which the dredges have worked overlaid the hard glacial drift to a depth varying from a few inches to 25 ft., the top of the hard material being very uneven, sometimes deep pockets of muck being found close to broad shallows. Except in the low water river bed, the uppermost 1½ ft. to 2 ft. of the muck is a solid crust held together by roots and weeds, and floating on the softer material beneath. These roots caused the dredges some trouble, as did also the uneven surface of the hard material beneath, but the chief difficulty arose in keeping the levees inclosing the discharge basin intact. The accompanying illustration, Fig. 27, shows one of these levees, with the discharge basin at the left and the channel with the dredge at work in it on the right. The levees were built of the upper crust of the muck and layers of hay, and were from 10 ft. to 15 ft. high. Time and again they were undermined by the muskrats or sunk into the soft muck and had to be rebuilt.

The channel cut by the dredges varied from 330 ft. to 420 ft. in width, and comprised all the soft material to within 18 ins. to 2 ft. of the hard glacial drift. The greatest depth cut to was 26½ ft., and occasionally the hard material was cut into, the pump throwing out many boulders from 8 lbs. to 15 lbs. in weight, through 2,800 ft. of pipe. The greatest elevation at which material was discharged was 15 ft. above the surface of the water. Ordinarily about 25% of the discharge was solid matter, although this varied from 80% to almost nothing. The specific gravity of the material was about 1.1 immediately after being deposited, and about 1.5 after a couple of weeks' exposure to the air.

The performance of these dredges was very satisfactory, the two excavating 1,538,387 cu. yds. in 882½ shifts, or 1,731.9 cu. yds. for each per ten-hour shift. For single days, of course, the capacity was much greater than this, running up to 7,000 cu. yds. per ten-hour shift. Usually the dredges worked twelve-hour shifts day and night, one hour's shut down for repairs, moving of dredges, etc., as an average, corresponding to one hour's work. All the dredge work was completed in 1894, and the dredges removed from the channel.

The dredging of the soft material on Section B was finished some time in July, 1894. Immediately after a levee was constructed across the channel and pumping began, laying dry the upper half of the section. It may be noted in passing that this levee failed Sept 11, flooding Section C, as already stated. By the last of October, 1894, the section was dry enough to lay railway and steam shovel tracks, and during November and December, 20,838 cu. yds. and 57,820 cu. yds., respectively, were taken out by steam shovels, scrapers and other methods of dry excavation.

In 1895 work was continued laying dry the two sections and installing an excavating plant. On Section B steam shovels loading into large cars hauled by locomotives, small cars hauled by mules, and scraper and wheel barrow forces have been used. Two shovels have been worked, and their output for five months has been as follows:

Month, 1895.	No. 10-hr. shifts.	Cu. yds. exc. per shift.
May	93	513
June	101	540
July	84	407
August	79½	465
September	102½	525

The excavation on Section A up to July, 1895, was done with wheel scrapers and teams, but in July two steam shovels, built by the Vulcan Iron Works, of Chicago, Ill., were put at work by Shailer & Schniglau, of Chicago, Ill., who took a subcontract to excavate 1,000,000 cu. yds. of glacial drift. These shovels were used in connection with a novel form of bridge conveyor, and their work, together with the construction of the conveyor, is described in Appendix A of this volume.

Section 1.

This section has been in the hands of two contractors since work was begun. On July 13, 1892, the first contract was awarded to Alfred Harley, of Chicago, at 27 cts. per cu. yd. for glacial drift, 83⅓ cts. per cu. yd. for solid rock, and $1.37½ per cu. yd. for retaining walls. The river diversion work was to be done first, according to the contract, but up to Sept. 1, 1893, very little had been done. Meanwhile Sections 2 and 4 had been taken from the contractors, and nothing was being done on the river diversion work on those sections. As it was important that this work should be completed immediately, the Sanitary District decided to do it by day labor, especially as at that time an army of unemployed were clamoring for work in Chicago, to whom the opportunity for employment would be a godsend. An agreement was entered into between the Sanitary District and Alfred Harler for Section 1, and McArthur Bros. for Sections 2 and 4, whereby they were to act as agents for the district, supplying all

necessary tools and equipment and superintending the work for a commission of 15% on the cost of the work. Unemployed men from Chicago were thus given work in large numbers, but it proved very expensive to the District, costing about 86½ cts. per cu. yd. for glacial drift excavation. In a report on the work Chief Engineer Isham Randolph said:

> This work may be regarded as an object lesson, clearly demonstrating from an economic standpoint the unwisdom of entering into any arrangement for carrying on the construction work of the District by the direct employment of labor.

While this work was going on, the contractor for Section 1 had done little or nothing on his contract proper, and as at the beginning of 1894 there seemed little prospect that he would do better, the Board of Trustees declared the contract forfeited Feb. 10, 1894. Some changes were made in the length of the section and other features of the work, and the work was readvertised, the bids being opened April 18, 1894. The lowest bidders were the Johnson & Bradley Co., who bid 39½ cts. per cu. yd. for glacial drift and 83 cts. per cu. yd. for solid rock. The total amount of their bid was $1,141,107. On May 23 the Board of Trustees awarded the contract to Griffiths & McDermott, the next lowest bidders, it being considered that the financial ability and experience of the Johnson & Bradley Co. were not such as would warrant the contract being let to them. It should be stated in this connection that this action was opposed by two members of the five composing the Committee of Engineering and Finance, who submitted a minority report recommending that the contract be let to the Johnson & Bradley Co. Indeed an injunction was secured by this company forbidding the Board of Trustees to let the contract to Griffiths & McDermott, but this was dissolved and the contract with the last named firm was signed June 6, 1894.

The total amounts of material to be excavated on Section 1, according to the latest estimates, are 1,348,406 cu. yds. of glacial drift and 536,024 cu. yds. of solid rock; 174,655 cu. yds. of the glacial drift being river diversion work. The prices at which Griffith & McDermott are doing the work are 42.9 cts. per cu. yd. for glacial drift, 80 cts. per cu. yd. for solid rock and $2.90 per cu. yd. for retaining wall. As stated in the description of Section A, a large amount of hard material was taken from Section 1 to fill in the trestle levee across the marsh between the river diversion and main channels on Section A.

Fig. 31 is a plan of Section 1 made early in 1895, which shows the arrangement of the tracks and inclines for handling the glacial drift. Owing to the irregularity of the ground adjacent to the channel it was found impracticable to use inclines until a level berm had been made for them by locomotives and cars. The first work of the contractors was therefore to take out the glacial drift with steam shovels and haul it to the berms and also to the trestle levee. Five locomotives and about 80 cars of about 6 cu. yds. capacity were used in this work. The plan, Fig. 31, shows plainly the arrangement of the tracks and the methods of operating the shovels. It will also be noticed from this plan that the cross-section of the channel changes from 202 ft. to 160 ft. wide on the bottom, or, in other words, that the earth channel stops and the rock channel begins on this section. The first retaining wall work also occurs on this section.

The glacial drift overlying the rock is very hard to excavate. It consists of a tough gravelly soil interspersed with a profusion of boulders varying from 1 ft. to 10 ft. in diameter. Hardly any of it can be excavated by steam shovels without blasting. Four Bucyrus special contractors' shovels are used.

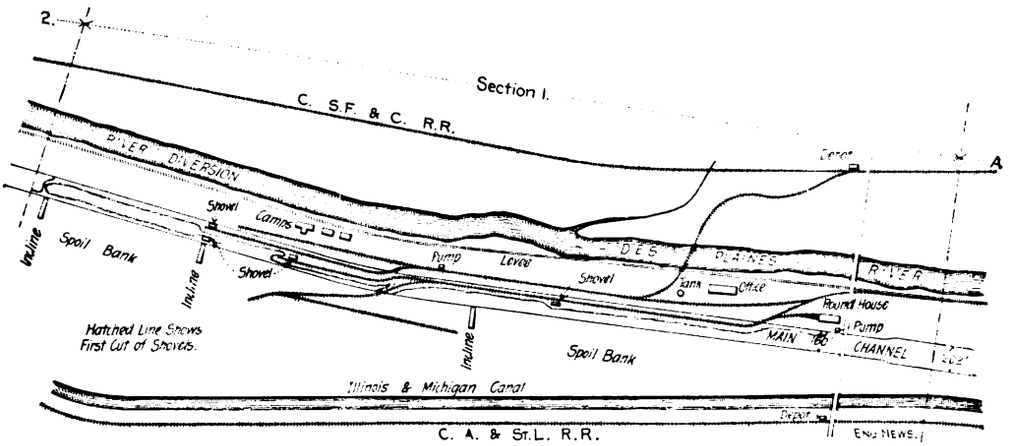


Fig. 28. Plan of Track System Showing Method of Excavation on Section 1.

GRIFFITHS & MCDERMOTT, Contractors, Chicago.

The following records taken from the report of the Superintendent of Construction show the output of these shovels for several months.

No. of shovel.	—Sept., '94.— Shifts.	Ave. cu. yds. per shift.	—Oct., '94.— Shifts.	Ave. cu. yds. per shift.	—Dec., '94.— Shifts.	Ave. cu. yds. per shift.
172	12	433	3	567	..	..
177	28	630	12	350	28	468
179	29	413	35	514	29	469
181	29	336	50	444	36	492

In November, 1894, the four shovels worked 97 ten-hour shifts and excavated an average of 500 cu. yds. per shift each. In January, 1895, the four shovels worked 103 shifts and excavated 215 cu. yds. per ten-hour shift each. The comparatively low average in January was due to the very cold weather and frozen ground.

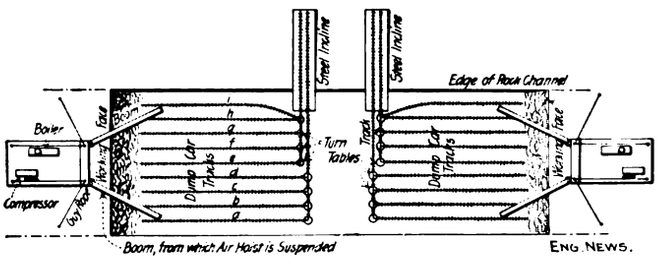


Fig 29. Plan Showing Position of Air Hoists, Car Tracks and Inclines, Section 1.

The shovels load into large cars hauled by locomotives and into cars hauled up the incline conveyors. The comparative capacity of the two systems for the month of May, 1895, was as follows:

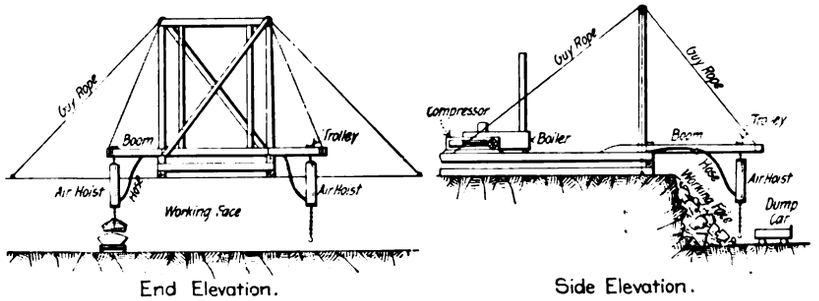
Shovel.	No. 10-hr. shifts.	Cu. yds. exc. per shift.
No. 177	43	279*
No. 184	38	282*
No. 179	20½	507**
No. 181	25½	482**

* Loading incline conveyor.
** Loading cars hauled by locomotives.

As soon as a level berm had been graded by the locomotive and cars, inclines much similar to those used on Sections M and L were constructed. These are all trussed structures, two being built of wood and iron and two of iron alone, and are mounted on trucks so that they can be moved along the berm of the canal. The top chord of the incline carries the tracks and has an inclination of about 30° from the horizontal. Each incline has an inclined trestle approach, which consist of short king post spans supported on trestle bents, which in turn rest on greased timbers so that they may be slid along as the work proceeds. The method of operation of these incline conveyors is exactly like that on Sections M and L. An open end car is hauled by a winding engine to the top of the incline, where it runs onto a tipple, which revolves and allows the load to slide out.

The two wooden inclines are used in handling glacial drift and the two iron inclines for handling rock. Fig. 29 shows the arrangement of the inclines and track system for the rock work, and also plans of the two derricks carrying the air-hoists used in loading large rocks. One incline with its system of tracks works west and the other east, the two completing the excavation as they proceed. Referring to the illustration, it will be seen that the cars are loaded at the face, hauled by mules along the tracks a, b, c, etc., to the turntables, where they are turned onto the incline tracks, hauled to the top and automatically dumped by the tipple arrangement. A reversal of this process brings the empty cars back to the face. It may be stated at this point that this is the only instance on the drainage Channel where the traveling incline and tipple are used for handling rock.

The cars used are made of steel, and are open at the forward end to allow the load to slide out as the tipple revolves. As will be seen from the plan, Fig. 29, there are nine tracks, and one car is used for each track. The loading is done by hand for all material that can be handled with a shovel or by a single man. For handling the larger stones a system of air-hoists is used. Fig. 30 shows the location of these hoists, the boiler, air-compressor, etc. The booms swing in horizontal circles and the hoist may be moved back and forward along the boom, being suspended from a trolley. In this manner any point on the working face can be easily covered. There are four hoists in the plant, two to each working face, and each has a cylinder 8 ft. long and 12 ins. in diameter. They are supplied with air from the



End Elevation. Side Elevation.

Fig. 30. Sketch Showing Air Hoist Apparatus for Loading Rock.

compressors on the framework as shown. These compressors, one of which is an 18 × 24-in. piston inlet Ingersoll-Sergeant and the other a Rand, also supply the air for the rock drills.

The manner of working the rock face needs but little explanation. A series of holes are drilled parallel to the face and transversely across the channel and the rock blasted out. A force of between 30 and 35 men is then distributed along the face and the cars loaded by hand and by the air-hoists. When the work was visited by a representative of this journal, six men were being used to operate the hoists on each face, this force changing from one air-hoist to the other. The right-hand hoist would be worked until all the large stones convenient to access were taken out, when the hand laborers would be set at work cleaning away the chips and small stones until more of the larger stones were laid bare. Meanwhile the operator would go to the left hand hoist and clean out the large rocks there. By this method the laborers were kept busy on small stones without delays to move the heavy rocks. Two sets of chains and grab-hooks were used with each hoist, two men taking care of each set. This allowed the hoist to travel from the face to the car with the minimum delay for fastening and unfastening the chains. While the hoist was traveling to the car, one pair of chainmen were making fast to a rock on the face, and while the hoist, having deposited its load in the car, was returning to the face, the second set of chainmen were unfastening their chain from the deposited load and getting it back to the face to attach another stone. One man operated the hoist and one man took care of the rope by which the boom was swung and the trolley moved along the boom. Generally one or two men remained on the face to loosen the stones and assist in fastening the chains when needed. The output of the incline conveyors working in solid rock was as follows for four months:

Month, 1895.	No. 10-hr. shifts.	Cu. yds. exc. per-shift.
May	38	165.8
June	67	160
July	91	164
August	97	187

In August, 1895, the contractors purchased two of the Brown cantilever cranes worked on Section 10—that section having been completed—and erected them on the solid rockwork. The construction and operation of this crane will be described in the article on Section 10. Considerable solid rock has been handled by steam shovels, but no exact record of their output is obtainable.

The section is very well equipped with shops, pumping stations, water tanks, and all similar plants necessary for the convenient and effective prosecution of work. Each of the pumping stations is provided with a 100-HP. boiler, an 80-HP. engine and a 12-in. centrifugal pump. In addition to this stationary pumping plant each shovel has a steam jet pump, and a 6-in. centrifugal pump, with an engine and boiler to drive it, has been mounted on a flat car which is run from one point to another as occasion demands. The blacksmith and machine shop is provided with a drill press, steam hammer, engine lathe, and various smaller tools. To provide water for the various purposes, a water main, supplied from the Desplaines River by two 4 × 6 × 4-in. Snow pumps, runs the entire length of the section.

CHAPTER VI.

RIVER DIVERSION CHANNEL AND SPILLWAY.

SO FAR little mention has been made of the important work of river diversion and its auxiliary construction. For long distances this route of the main channel occupied the bed the Desplaines River, and almost its entire length was subject to inundation during flood seasons. It will be readily seen, therefore, that plans for diverting this stream had to be carried to completion before much work could be done on the main channel. These plans provided for the construction of a river diversion channel running almost parallel with the main channel and separated from it by a levee high and strong enough to hold back the most excessive floods. Since, however, only part of the flood waters had normally gone down the river through Lockport and Joliet, Ill., it was inadvisable to force the entire volume of water through that channel until it had been enlarged to the proper size. The enlargement of the channel through Lockport and Joliet could not easily be made until a later date, and so some temporary expedient was necessary to dispose effectually of the surplus flood waters without either forcing them through Joliet or allowing them to inundate the main channel. A safety valve in the shape of a spillway was therefore constructed near the head of the river diversion channel, which allowed all the flood waters beyond a certain amount to flow into the Ogden Ditch and Chicago River.

The river diversion channel begins on Section F and continues to the end of the main channel, sometimes following the old bed of the Desplaines River and sometimes an artificially-excavated channel. The location of this channel is shown in the general map of the drainage channel work. Altogether there are 13 miles of artificial channel, 200 ft. wide on the bottom and with side slopes of 2 to 1. The levee separating the river diversion from the main channel is 19 miles long. The work of constructing the river diversion channel calls for no especial mention. Generally the diversion channel on each section of the main channel was excavated by the contractor of that section, but in some instances the Sanitary District did portions of the work for the purpose of giving work to the unemployed poor of Chicago.

Fig 31. Spillway Near Head of River Diversion Channel.

The spillway at the head of the river diversion channel is a concrete dam capped with cut stone, and is 397 ft. long. The crest of the spillway is 16¼ ft. above Chicago datum, which prevents any flow toward Chicago until the flow of the Desplaines River has reached 300,000 cu. ft. per minute, and furthermore limits the possible height of water in the river to an elevation between 3 and 4 ft. above the crest of the spillway, thus insuring against an overflow of the south lines of the river diversion. It also limits the maximum flow toward Joliet to about 400,000 cu. ft. per minute.

Originally the flow toward Chicago commenced

when the flood passing this point of the river reached 50,000 cu. ft. per minute. When the channel through Joliet is enlarged so as to accommodate the entire flood waters, the crest of the spillway will be raised so as to prevent any flow toward Chicago.

Fig. 31 is a general view of the spillway, and Figs. 32 and 33 show a plan and several sections of the masonry. Stone masonry is used for capping the dam and facing a portion of the wing walls, but for all other parts of the structure concrete is used. The body of the concrete was composed of one part Louisville cement mortar and two parts broken stone. This mortar was made in the proportion of 300 lbs. of cement to 7 cu. ft. of sharp, clean sand, and the broken stone was required to be of such size that its greatest dimensions would pass a 2-in. ring. The cement and sand were first mixed dry, and then passed through a ¼-in. mesh sieve, and wetted as needed for use, the broken stone being added to the wetted mortar. For plastering the exposed surfaces of the concrete work, German Portland cement mortar composed of 400 lbs. of cement to 3 cu. ft. of sand was used. This coating of plaster varied from ½ in. to 1 in. thick, and cost 75 cts. per sq. yd. The cost of the concrete was $6 per cu. yd. The figures of cost include everything—material, molds, etc.—including the hauling of all material about one mile from the railway by teams.

The method of doing the work was very simple. The Sanitary District entered into a contract with McArthur Brothers, of Chicago, whereby that firm was to furnish all labor, material and superintendence, and render bills for the labor and material to be paid by the Sanitary District, which was also to pay 10% on the cost of the work for superintendence. In shorter words, McArthur Brothers acted as agent of the Sanitary District for this particular work. The rock foundation was first cleaned, and then the concrete was placed in suitably-shaped molds and tamped in 6-in. layers. The capstones and other stone masonry were laid as the concrete work progressed to suitable points. It may be stated that the capstone masonry, which

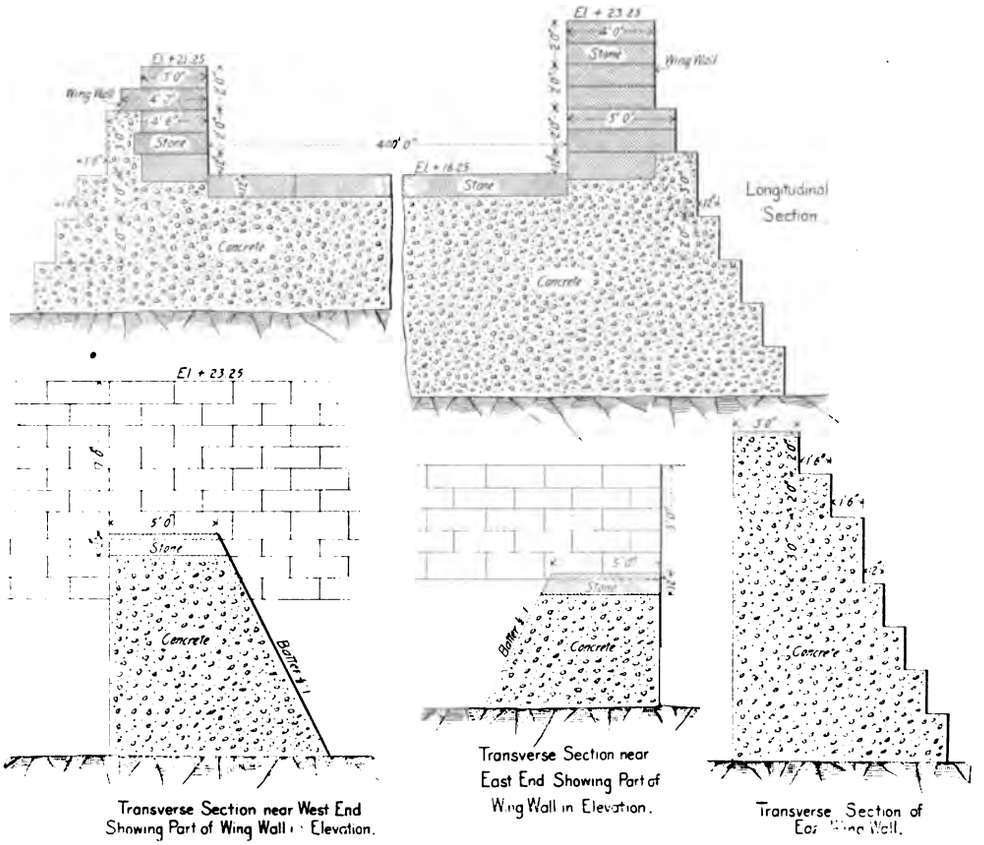


Fig. 33. Sections of Spillway Showing Character of Masonry

consisted of dimension stone laid in Portland cement mortar, cost $16.50 per cu. yd. The total cost of the spillway was $20,518.

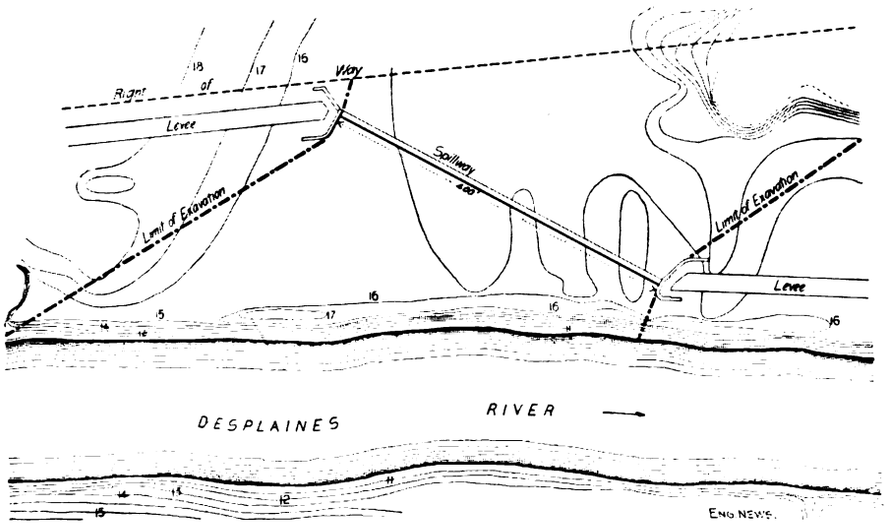


Fig. 32. Mao Showing Location of Spillway.

The spillway has been called upon but once so far to act for the purpose for which it was constructed. In March, 1894, water flowed over the crest for a period of 61 hours. This flood, but for the intervention of the spillway, would have for the most part entered the Chicago River, and like its predecessors, swept pollution and disease out into the lake to be drawn into the water-works inlets. This may perhaps be said to be the first substantial benefit which the city of Chicago has reaped from her great sanitary work.

CHAPTER VII.

STEAM SHOVELS.

THE successful bidders for the different sections of the Chicago Drainage Channel were for the most part men who had received their contractors' training in building railways. It was natural, therefore, that they should bring to the work the machine which their railway experience had shown to be absolutely indispensable where large amounts of excavation had to be done, and we find the American steam shovel used in large numbers and in a great variety of designs all along the channel. Indeed the steam shovel has been the prime factor in the extraordinarily economical handling of large quantities of earth, which has characterized the canal work. While the methods of conveying the spoil from the canal have varied widely on different sections, the system of excavation proper, in earth of course, has been the same on all—viz., by steam shovels. It seems proper, therefore, notwithstanding the familiarity of this device to American engineers, to describe with some carefulness the more prominent of the various types of shovels used, although some things that we say may repeat what is already familiar to many of our readers.*

Practically all of the steam shovels used on the canal have been furnished by six manufacturers—viz., the Bucyrus Steam Shovel & Dredge Co., South Milwaukee, Wis.; the Marion Steam Shovel Co., Marion, O.; the Osgood Dredge Co., Albany N. Y.; the Vulcan Iron Works Co., Toledo, O.; the Vulcan Iron Works, Chicago, Ill., and the Toledo Foundry & Machine Co., Toledo, O. Each of these manufacturers is represented by two or more shovels, and generally by two or three weights and patterns of shovels. These machines, of course, differ from each other in special features and details, but they are all alike in their general construction and in the principle of operation. Each consists of (1) a strong framework or car, mounted on wheels, which is the base to which all working parts are attached; (2) a swinging crane carrying the dipper and dipper handle, and which is attached

Fig. 34. Barnhart Style AA Shovel at Work on Section M.

MARION STEAM SHOVEL CO., Marion, O., Builders.

* A valuable series of articles on Steam Shovels and Steam Shovel Work was contributed to Engineering ing News in 1893 by Mr. E. A. Hermann, M. Am. Soc. C. E., and afterwards published in book form with additional matter. These articles describe in detail all of the shovels mentioned here and may be consulted for special details.

to a mast or post at the front end of the car; and (3) a boiler, engine and other mechanism which are placed on the floor of the car, and operate the crane and dipper by means of chains, wire ropes or other devices. All of these features are clearly indicated by the accompanying illustrations.

The differences between different makes of steam shovels are chiefly in the methods of constructing these three essential parts. For example the crane may be a trussed crane attached to a vertical mast, as in the Victor shovel, or it may be a boom pivoted at the bottom and guyed to the car frame at the top as in the Barnhart shovel. The engines may be vertical or horizontal and may apply their power through friction clutches or by direct gearing. These differences, as far as they pertain to the types of

The car is 10 × 26 ft., built of steel channels and I-beams as follows: The floor rests on six 9-in. 22-lb. channels and two 9-in. 30-lb. I-beams, all of which are 30 ft. long. At the front end these channels and beams are fastened together with a ¾-in. steel plate 17 ins. wide and at the rear end a similar plate connection 1-in. thick and 9 ins. wide is fixed. The bolster under the car and the cross-beams are of oak with 7-in. channels bolted on each side. To convey the strain of digging to the floor, the frame of the car is composed of four bents, each of which is made up of 7-in. 18-lb. channels, except the cap and sill of the forward bent which are 8-in., 22-lb. channels. At the top corners these bents are connected by 7-in., 27-lb. I-beams running lengthwise of the car. The bents are thoroughly braced to each

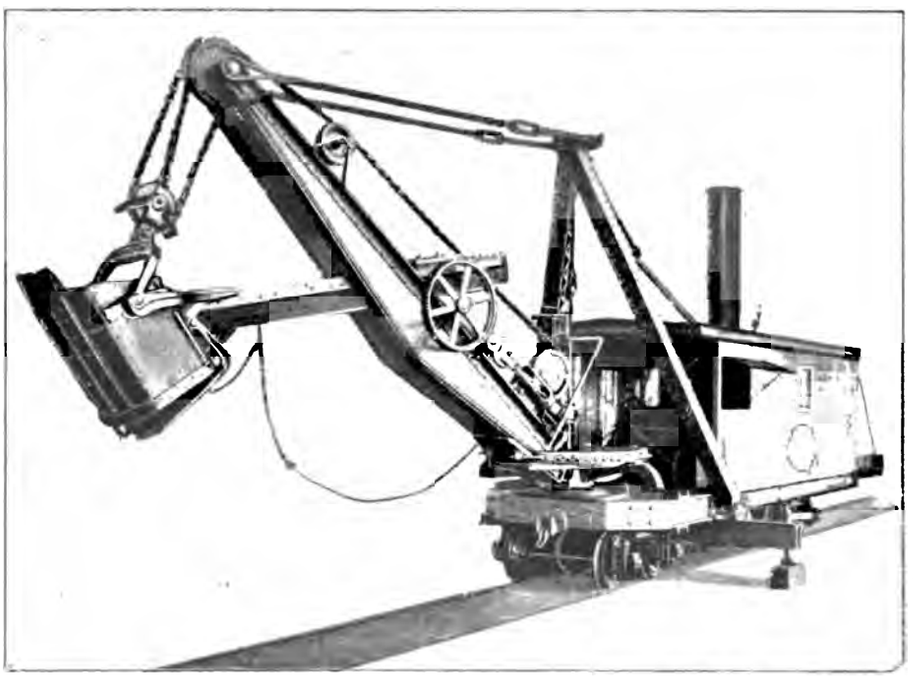


Fig. 35. Bucyrus Special Contractor's Shovel, Pattern O.

BUCYRUS STEAM SHOVEL & DREDGE CO., South Milwaukee, Wis., Builders.

shovels at work on the Drainage Channel, will be described briefly in the following paragraphs. As regards the records of work done by the different shovels, such figures as are available are given in the articles describing the several sections of the channel, where the conditions of the work and the character of the excavation, both prime factors in any comparison of steam shovel work, are fully described.

Barnhart Shovel.—This shovel is manufactured by the Marion Steam Shovel Co., of Marion, O., and is illustrated at work on Section M in Fig. 34. The shovel illustrated is one of the company's type AA, as are most of the shovels of this company's make in use on the Drainage Channel.

other and to the floor with 1½-in. and 1¾-in. steel rods provided with turnbuckles. It should also be stated that the members of these bents consist of two channels placed flange to flange and bolted together through cast iron fillers, and that an A-frame of 15-in. 50-lb. channels, to which the crane suspension rod is attached, runs back into the car and is firmly attached to the framework.

From this anchorage the crane suspension rod, 2½ ins. in diameter, runs to the front tip of the boom, to which it is connected by heavy springs so as to relieve the machinery from sudden shocks in digging. The boom is made of oak timbers trussed with steel rods, and the dipper handle is a 5½ × 14-in. oak timber. The foot of the boom rests in a

socket in the casting that forms the turntable hub. The turntable is 8 ft. in diameter, with its rim and arms made of steel plates and iron channels, and is mounted on a heavy cast iron base forming a journal 16½ ins. in diameter and 16½ ins. long.

Two 10 × 12-in. vertical engines operate the hoisting and swinging drums by means of cone frictions actuated by two friction clutches. The hoisting drum is 14 ins. in diameter and the swinging drums are 10 ins. in diameter and all these are mounted on the same shaft. From the drums the power is conveyed to the dipper and turntable by means of chains. A friction clutch geared to the hoisting drum enables the dipper to be fed independently of the hoisting chain.

The jack arms are of new design. The main brace is made of two 7-in. channel irons, each weighing 18 lbs. to the foot, fastened in position by wrought iron braces. The jack is so constructed that it can be swung alongside of the car when passing an obstruction, and is also arranged so that the jack screw can have its bearings at a distance of 9 ft. 8 ins. from the center of the car, or can be made to have its bearing very close to the side of the car. This is an important item in making a through cut, and other work where it is necessary to take cars past the machine. The jacks are so placed that the boom can be swung considerably past a right angle, which is also very important in most work. The jack screws are 3⅞ ins. in diameter.

Altogether about 20 Barnhart shovels have been used on the canal work, most of which were of the AA pattern. Figures relative to the work of the AA pattern shovel have been given in the articles on Sections K and I, M, L and others.

Bucyrus Shovel.—Four different patterns of shovels manufactured by the Bucyrus Steam Shovel & Dredge Co., South Milwaukee, Wis., are being used on different sections of the channel. These are, the No. 1, Crane; No. 1, Boom; No. 0, Boom, and No. 0, Special Contractors' Patterns. The last-named pattern was designed specially for the hard, indurated clay and cemented gravel excavation on the drainage channel, but the three others are the regular patterns which have been on the market for some time for general railway work.

The following table gives the general features of the No. 1 Crane and No. 1 Boom patterns in sufficient detail to give one a fair understanding of their construction:

	Pattern.	
	No. 1, Crane.	No. 1, Boom.
Car	10 × 30 ft.	10 × 30 ft.
Trucks	M.C.B., 60,000 lbs.	M.C.B., 60,000 lbs.
Mast	3½-in., cast iron	Steel, A-frame.
Boom	19 ft., 19 ft. rad.	23 ft., wr'ht iron.
Dipper	1¾ cu. yds.	1¾ cu. yds.
Dipper-handle	Oak, 14 ft.	Oak, 14 ft.
Thrust motion	Friction clutch	Friction clutch.
Chains—		
Hoisting	1 in.	1 in.
Swinging	⅞ in.	⅞ in.
Engine	2-cyl., 8 × 12 ins.	2-cyl., 8 × 12 ins.
Boiler	Vert., 4 × 8½ ft.	Vert., 4 × 8½ ft.
Capacity tank	7 hours	8 hours.
Jack arms—		
Material	Wrought iron	Wrought iron.
Size screw	Steel, 4½ ins.	Steel, 4½ ins.
Weight	35 tons	45 tons.

Fig. 36. Victor Shovel, Class Special, for Sections A and B.

TOLEDO FOUNDRY & MACHINE CO., Toledo, O., Builders.

The No. 0 Boom pattern is similar in its general features to the No. 1 Boom pattern, but is heavier, weighing 52 tons instead of 45 tons, and has more steel in its construction. It has a double cylinder, 10 × 12-in. engine, and the dipper is 2¼ cu. yds. capacity.

From a careful study of the operation of the shovels just described in excavating the cemented gravel, the builders designed the No. 0, Special Contractors' Shovel shown in Fig. 35. A general detail drawing of this shovel was published in Engineering News, March 21, 1895. The principal features which distinguish it from the No. 0 Boom pattern, beyond its much greater weight, are (1) the high A-frame built up of steel channels and

plates; (2) the powerful independent thrusting engines on the boom instead of the friction clutch thrusting arrangement, and (3) the jack beam, which also serves as a base for the A-frame. These details are all quite clearly shown by the illustration.

The A-frame is 14½ ft. high, and is made very strong to carry the strain of the heavy boom and dipper handle, which are fully as large as are used in heavy lake dredges. It will be noticed also that the dipper has a sharp outward pitch, so that the thrust of the engines will be most effective, and also that it is fastened to the handle by a single casting. The reason for this solid construction will be readily understood when it is stated that the engines on the boom have a thrusting power of 30 tons. Another feature of this part of the design is that the lines of stress in the dipper handle and dipper bail intersect in a point close to and in line with the dipper teeth. The engines are 10 x 14 ins. with two cylinders, and the power is conveyed to the drums by outside band frictions. The boiler is of the locomotive type.

Altogether 26 Bucyrus shovels have been worked on the canal. Figures relative to the work of the No. 1 Boom pattern will be given in the description of Sections 2 and 4, where also the work of the No. 0 Special Contractors' pattern will be described. Similar records of the work of the No. 0 Boom pattern have been given in the descriptions of Sections M and L, and Section D.

Victor Shovel.—This shovel is manufactured by the Toledo Foundry & Machine Co., of Toledo, O., two patterns—viz., Class No. 1 and Class Special—being used on the drainage channel. Fig. 36 is a view of one of the Class Special shovels which is now at work on Sections A and B. Some half-dozen shovels of the two classes have been worked on the canal.

The Class No. 1 shovel weighs about 46 tons, and is 56 ft. long and 9½ ft. wide over all. The crane is built of steel, and is hung from a hollow cast iron mast, with the swinging drum at the top. Ordinarily the swinging is done by two steam cylinders placed on the top of the car, but in one of the shovels used on the canal a chain operated by a pair of 6 x 6-in. reversible engines is used. The thrusting motion is obtained from a pair of independent engines mounted on the crane, and the hoisting motion is imparted by a chain, which extends from the hoisting engine drums to the foot of the mast, and hence up through the hollow mast to the dipper. The jack arms are steel castings fastened to the car floor and braced to the top of the mast. Steel jack screws work in the steel castings.

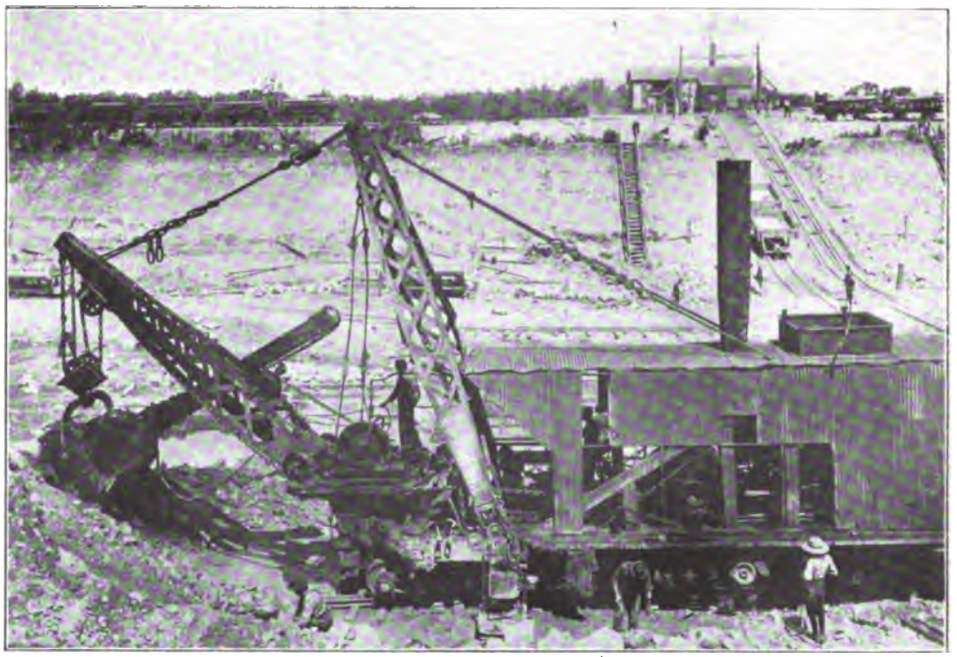


Fig. 37. Osgood Steam Shovel at Work on Section 4.

OSGOOD DREDGE CO., Albany, N. Y., Builders.

The Class Special shovel, which is illustrated, is similar to the Class No. 1 in its construction, but is larger, weighing 54 tons, and being 10 ft. wide and 65 ft. long over all. In both patterns the car is built of steel beams and channels, and is mounted on standard M. C. B. Fox pressed steel trucks. All gearing is of steel. The water tank is placed under the car, and has a capacity of about one-half day's supply of water.

Osgood Shovel.—Only three "steam excavators" of

the type manufactured by the Osgood Dredge Co., of Albany, N. Y., are being used on the drainage channel. All of these are in operation on Sections 2 and 4, and all weigh 70 tons each. With the exception of the great 125-ton land dredge, built by the Marion Steam Shovel Co. for Section E, which hardly comes into the category of shovels for general work, these are the heaviest steam shovels on the canal.

A description of one of these shovels will answer for all, except in minor details. The car is 33 ft. × 9 ft. 8 ins., and is built of white oak and mounted on M. C. B. 60-000-lb. trucks. The boom, which is guyed from a high A-frame resting on an 18 × 18-in. oak jack beam, is 30 ft. long, and has a radius of delivery of 34 ft. The main engine is a two-cylinder, reversing, 10 × 12-in. engine, and the crowding engine, which is mounted on the turntable, is 6¼ × 8 ins. Unlike most shovels, the swinging and hoisting in this machine is done by the same chain; the machine is similar to a clamshell dredge in this respect. The thrust is given to the dipper by a chain, one end of which is attached to the rear end of the dipper arm, the chain then passing along its underside around a sprocket wheel, and thence to a fastening at the front end of the dipper arm. The sprocket wheel is revolved by means of a chain from the thrusting engine. The boiler is of the locomotive type, 54 ins. in diameter and 7 ft. long.

These three Osgood shovels have been worked in the cemented gravel of Sections 2 and 4, and have done excellent work. Somewhat detailed figures of their output will be given in the article on those sections. Fig. 37 is a view of one of the Osgood shovels working in cement gravel on Section 4.

Warrington Shovel.—This is an entirely new design of steam shovel, the two on Section A of the canal being the first ever built. As this machine was illustrated and described in Engineering News of July 4, 1895, it will be only briefly mentioned here. The car and framework is steel throughout, and is mounted on Fox pressed steel trucks. The crane is rigid and the swinging circle is overhead. A double-cylinder thrusting engine controls the thrusting motion of the dipper, and the hoisting, jacking, swinging and propelling are done by the main engine. The shovel is manufactured by the Vulcan Iron Works, of Chicago, Ill.

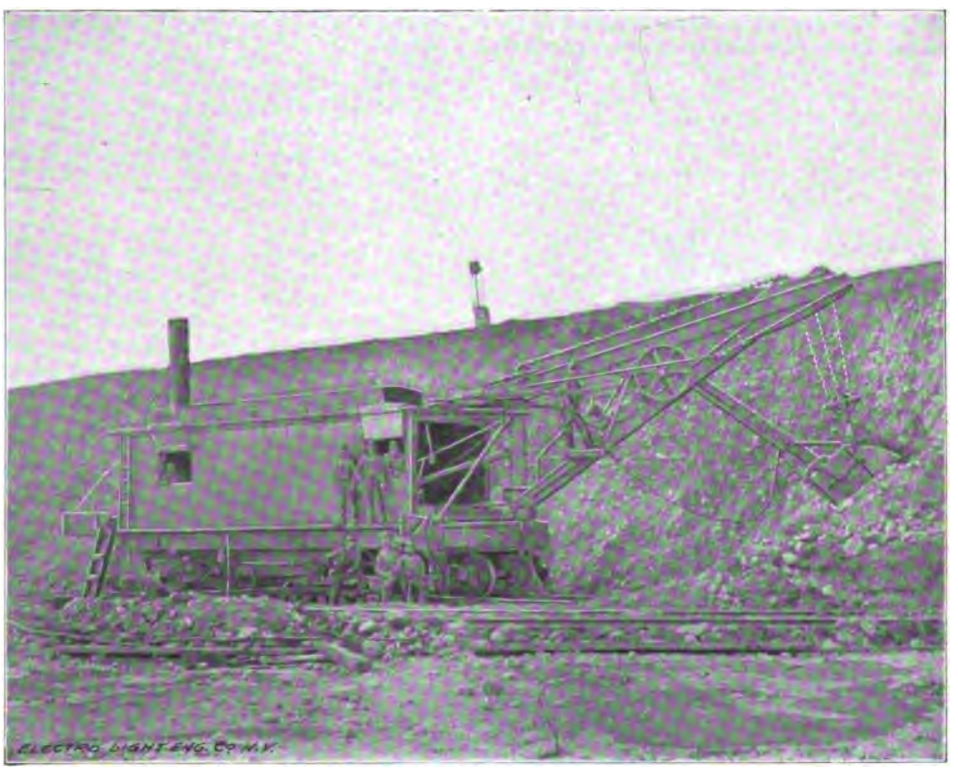


Fig. 38. Giant Shovel at Work on Section 14.

VULCAN IRON WORKS CO., Toledo, O., Builders.

Giant and Little Giant Shovels.—These shovels are manufactured by the Vulcan Iron Works Co., of Toledo, O., and the two are very similar in their general design and construction, except that the Little Giant is mounted on broad-tired traction wheels to travel on ordinary roadways, and is much

lighter. The framework and car are of steel, as is also the crane, which is hung from a cast iron mast with an overhead swinging circle. The thrusting motion is obtained by an independent engine mounted on the crane, and the swinging motion and hoisting motion are each obtained by an independent engine. The boiler is of the vertical type.

Both the Giant and Little Giant shovels have been worked on the channel, and figures of their output will be given in the articles describing Sections 6, 9 and 14. Fig. 38 is a view of one of the Giant shovels at work on section 14.

The foregoing will give a pretty clear idea of the various types of steam shovels which have done the earth excavation on the drainage channel. Owing to the constant changes in the equipment, it is impossible to say just how many shovels have been worked from first to last, but a rough estimate places it between 60 and 70. The question naturally arises: How have these shovels shown up in the canal work? This is a rather difficult question to answer fairly. No one weight or style of shovel has shown itself superior in all clases of work; but for the hardest indurated clay and cemented gravel excavation the heaviest types described have proved too light, while the lighter types could not be worked at all. A somewhat careful inquiry has failed to show that failure occurred in any particular part of the shovel more than another, but rather that the structure throughout was too weak for the heavy work it was called upon to do. This statement, it will be understood, refers to the hardest digging.

CHAPTER VIII.

LIDGERWOOD TRAVELING CABLEWAYS.

ONE of the devices most extensively used on the Chicago drainage channel for handling solid rock is the Lidgerwood traveling cableway, 19 of these machines altogether being employed on the work. The use of this device on so large a scale, and the various modifications which the traveling feature and the peculiarities of the work have necessitated, make a somewhat extended description necessary The Lidgerwood fixed cableway is well known to engineers, but the adaptation of this system, and so far as we know, of any modern cableway system, to travel along a series of tracks so as to accommodate different parts of the work at different times as necessity demands is something new. The broad idea of the traveling cableway is, however, quite old, a device of this character having been patented nearly 44 years ago by a Mr. Plucnet, a Frenchman, and curiously enough the patent drawings show it applied to canal work. It is not known that this device was ever used, and, so until there is evidence to the contrary, we are justified in assuming that the first extensive use of the traveling cableway was on the Chicago drainage channel.

The Lidgerwood traveling cableway is used on seven different sections of the canal, and the main dimensions of the different cableways and the number used on each section are as follows:

Secs.	No. used.	Span, ft.	Height towers, ft.
2	2	643 & 576	93, both.
3	4	700	93 and 73
4	2	650	" " "
5	1	700	" " "
6	4	725	93, both.
7	1	657	93 and 73
8	4	700	" " "
8	1	550	83, both.

These cableways are used, of course, merely to convey the rock from the pit to the spoil bank, after it has been blasted and loaded into skips. Two conditions were to be satisfied in performing this work: (1) to move the cableway along the canal easily and expeditiously, and (2) to pick up, carry away and dump the load as quickly and cheaply as possible. Ordinarily, where cableways had previously been used, the load was of value, and was to be conveyed from one place to another place where it was wanted for some useful purpose. Here, on the contrary, the load was of no value and the point to be gained was to get rid of it in the cheapest manner. The usual method of lowering the loaded skip to the ground and unloading by hand was therefore not economical, and the aerial dump (Fig. 44) was devised. This method of dumping the skips in the air and "on the fly," so to speak, has contributed largely to make the cableway an economical device for handling rock on the canal.

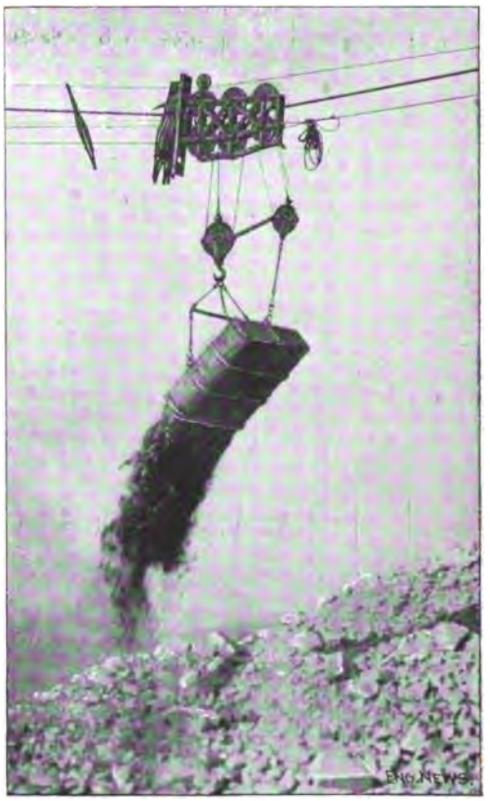


Fig. 44. Dumping a Skip While in Motion, Lidgerwood Traveling Cableway.

Turning now to the consideration of the traveling cableway, as manufactured by the Lidgerwood Mfg. Co., of New York, N. Y., for the Chicago drainage channel work: Fig. 39 shows a general elevation of one of the 700-ft. span cableways extending over the canal excavation and spoil bank as

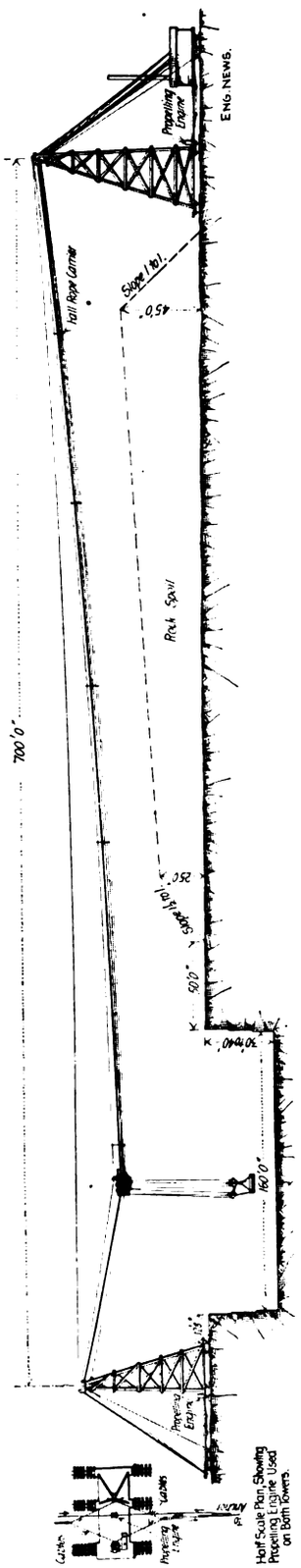


Fig. 39. General Elevation of Lidgerwood Traveling Cableway for Conveying Rock.

THE LIDGERWOOD MFG. CO., New York, N. Y., Builders.

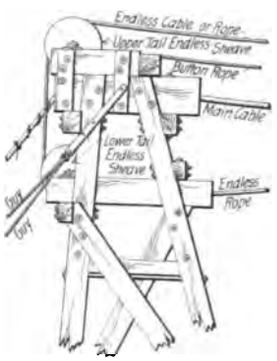
it is located in actual work. It will be noticed that the traveling feature consists simply in mounting the towers—which are firmly anchored to the ground in the ordinary fixed cableway—on cars running on a series of tracks and providing suitable mechanism for propelling the cars. The gage of the tracks and the various dimensions of the towers, cars, etc., are clearly shown in the drawing.

The towers and cars are of simple framed construction in wood, properly counterweighted and built sufficiently strong to withstand the pull of the cables. Figs. 40 and 41 show the arrangement of the sheaves and cables at the tops of the head and tail towers, respectively, and also the construction of the carriage and skip. The head tower is the one beneath which the hoisting engine for furnishing power for operating the plant is located, and the tail tower is a support for the opposite ends of the cables. As will be seen, there are in all five cables used in operating the carriage and skip—viz., the main cable for carrying the carriage; the traversing or endless cable for hauling the carriage; the hoisting cable for raising and lowering the load; the dumping cable for dumping the load, and the button cable for distributing and supporting the fall rope carriers. Of these cables only the dumping cable is peculiar to the traveling cableway as used on the canal, and is the only one whose function and operation need to be described in any detail. The main cable is made of crucible steel, and is 2¼ ins. in diameter with a hemp center. Its breaking load is 155 tons. As stretched between the towers this cable has a sag of 5 ft. per 100 ft. The traversing and hoisting cables are ¾ in. in diameter, and the button cable is ⅝ in. in diameter.

The duty of the dumping rope is to dump the skip in mid-aid. It is attached to a fall block, which in turn is attached to the rear end of the skip by a suitable chain and hook, and extends thence to the dump sheave at the top of the tower, and thence to the engine drum. As the dumping rope and hoisting rope are wound on the same drum, it will be seen that all their motions coincide in direction and character. It will be seen also that by winding the dumping rope temporarily at a higher speed than the hoisting rope, the rear end of the skip will be raised and the load will slide out of the front end. This is exactly what is done.

Two devices have been designed by which this temporary increase in the speed of the dumping rope can be secured. The older of these, and one which is used on all of the cableways on the canal is the Locher aerial dump, invented by Mr. Chas. H. Locher, of the firm of Mason, Hoge & Co., contractors for Sections 6, 7, 8, 11, 12 and 13. Fig. 42 shows the construction and operation of this dump. The drums A and C are of the same diameter, and are for the hoisting rope and dumping rope, respectively. Between them is the larger drum, B. The dumping rope comes from the top of the tower passes between two friction rollers, D, carried by a frame which slides on the rods E E. The lever F is used to slide the friction roller frame backward and forward. The full lines show the normal positions of the lever, frame and dumping

rope. To dump, the lever is thrown into the position shown by the broken lines, bringing the frame and rope over the drum B, which, being of a greater diameter than drum A, causes the dumping rope to travel at a higher speed than the hoisting rope, and therefore the skip to dump its load as just explained. It will be noticed that with this device the load can be dumped on one side of the canal only without a change in the machinery.



Tail Tower.

Fig. 40 Details of Top of Tail Tower.

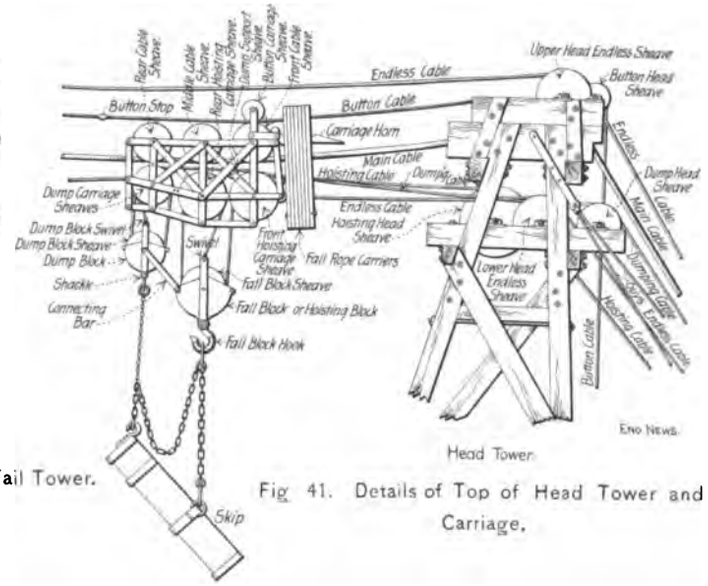


Fig. 41. Details of Top of Head Tower and Carriage.

The second aerial device mentioned is somewhat more complicated and cumbersome in its operation and application, but it enables the skip to be dumped on either side of the canal at will without changing the machinery. This dump was designed by Mr. A. M. Mullinix, Superintendent for Gilman & Co., contractors for section 3, and is used on three cableways on that section only. The operation of the device is shown in Fig. 43. Two vertical ways, A A, are placed as shown in the section of the power house. Between these ways slides a carriage, B. Normally this carriage is held near the tops of the ways by the counterweight, C. To the bottom of the carriage is attached the rope, D D. Now, as the dumping rope passes over the fixed sheaves E E, it will be seen that if the carriage B is hauled down toward the bottom of the ways a loop is taken in the rope, which means that temporarily the dumping rope travels faster than the hoisting rope, and the skip is dumped. To haul the carriage down the ways the rope D D is used. This rope, as will be seen, passes under the sheaves F F, and to the placer G operated by the lever H, and has a loop at its top end, which when thrust forward catches onto the hook I and winds around the drum. As soon as the load is dumped, the drum is of course reversed, and the loop and carriage are hauled back to their normal positions by the counterweight.

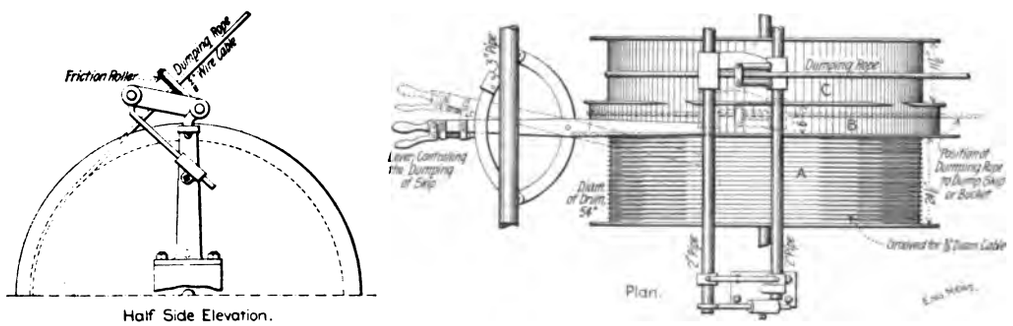


Fig. 42. Locher Aerial Dump, Lidgerwood Traveling Cableway

The foregoing description, with the illustrations, will give a fair general idea of the operation and construction of the two aerial dumping devices, and various other parts of the cableway. The power

machinery by which the dumping, hoisting, etc., are done, is all very simple, consisting merely of a 70-HP. boiler and 10 × 12-in. hoisting engine. For propelling the cableway along the canal a small reversible hoisting engine is placed on each car, which operates the system of blocks, as shown in the plan of the tail tower, Fig. 39. Simply by reversing the engine the car can be hauled backward and forward at will. The hoisting machinery gives the skip a hoisting speed of about 250 ft. per minute, and the carriage a traveling speed of approximately 1,000 ft. per minute. The total weight of the cableway, cars, skips and all, complete, is about 450,000 lbs., and its total cost about $14,000.

The method of working the cableways is the same in its general features for all sections on which they are used, but of course the details of operation differ on different sections. In the same way the cost of operation and capacity of the various machines differ accordingly as the management and superintendence are good or bad, with the hardness of the rock, etc. For these reasons, only the general methods of operation common to all sections will be described here; the various minor details peculiar to each section being described in the article on that section.

The work is usually done on a face about 12 ft. high, the stone being broken up by drilling a series of holes from the top down, transversely across the canal and parallel to the face, and blasting the rock out from the face. The skips are strung across the canal at the foot of the face and loaded with the broken rock by hand. The larger pieces of rock are chained out without being loaded into the skips. Considerable stress is laid upon this feature by the manufacturers, as it saves the time, labor and material that would otherwise be required to break the large rocks so that they can be carried by the skips. Stones weighing from six to eight tons can be handled in this way without injury to the cableway.

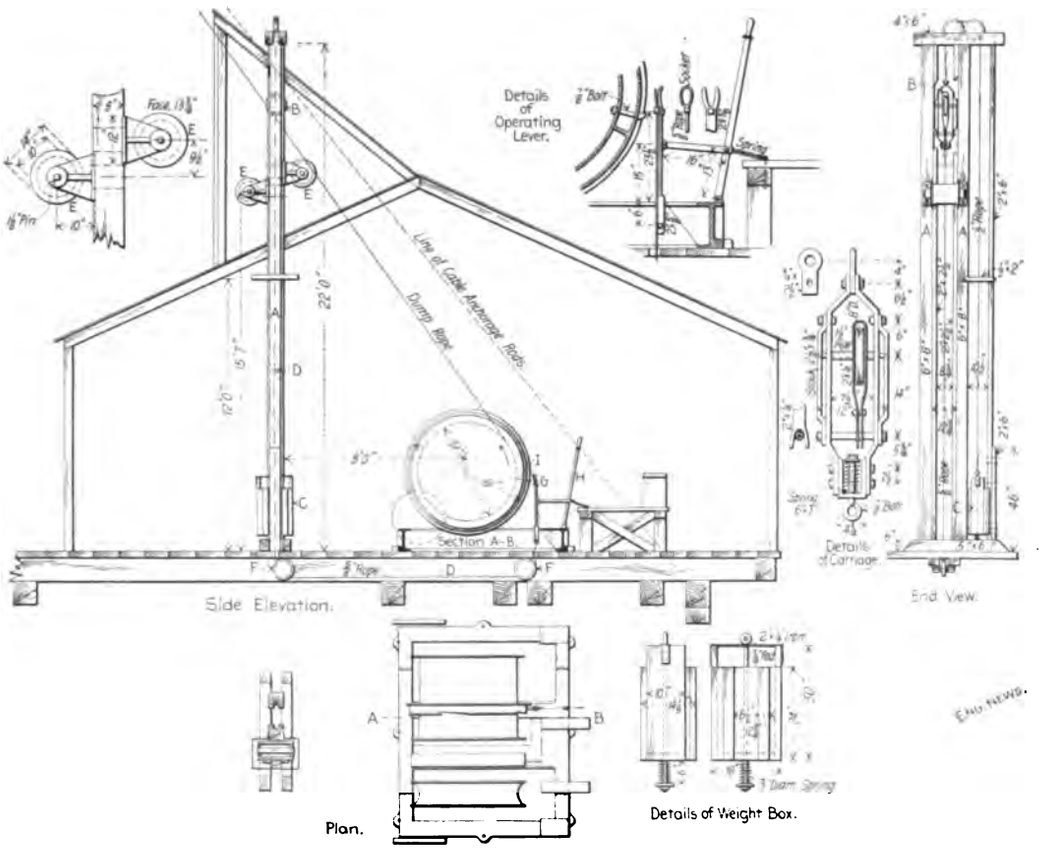


Fig. 43. Mullinix Aerial Dump, Lidgerwood Traveling Cableway.

As an indication of this ability to handle large rocks, the dimensions of a stone found by the writer in a cableway spoil bank are given—viz., 7½ × 4 × 3½ ft., which equals 105 cu. ft., or 3.9 cu. yds., and gives a weight of approximately 16,800 lbs.

The danger from chaining large rocks is very little, since they can be handled horizontally at any height desired, and consequently if the chain does slip

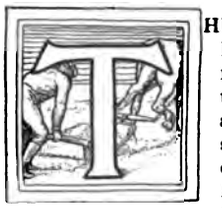
little damage is done. Moreover, the general practice is to do this handling of heavy pieces during the noon hour when all but three or four men are away, so that when the men return only fine material remains to be handled, and the skips can be loaded without delay to handle large rocks.

These skips are simple in construction. They are made of boiler plate steel, and are about 7 × 7 × 2 ft. deep, and weigh empty about 2,300 lbs. Their capacity is about 1.9 cu. yds. of rock in place.

The force required to operate the cableway proper consists of an engineman, fireman, signalman and generally a rigger, whose duty it is to attend to the oiling, changing of worn-out sheaves, etc. Sometimes one rigger has charge of two or more machines. Of course, the wages of these men vary somewhat, but as a general thing the aggregate wages of the engineman, fireman and signalman together amount to about $5.50 per 10-hour day. The rigger usually gets from $2 to $2.50 per day. The other items of expense entering into the operation of the cableways vary, of course, on each section, and so far as possible they will be given in the articles on the different sections. For a similar reason it is not possible to give any definite figures regarding the capacity of the cableways to handle rock, which are of general application. It may be said, however, that the amount handled per 10-hour shift is shown by the monthly progress reports of the Superintendent of Construction to run all the way from 200 cu. yds. to 500 cu. yds. The manufacturers set 500 cu. yds. per 10 hours as good work, with good superintendence and conditions similar to those on the canal. A full analysis of these conditions and the results of the work on the different sections will be given in future articles.

CHAPTER IX.

THE LEMONT DIVISION.



HE Lemont Division of the Drainage Channel extends from the east end of Section 2 to the west end of Section 8, a distance of approximately seven miles, and is under the charge of Mr. Hiram A. Miller, Division Engineer, Lemont, Ill. Throughout the entire division the channel has a section practically rectangular and 160 ft. wide on the bottom, and for most of its length there will be retaining walls on both sides of the channel. In this division the excess of rock excavation over glacial drift excavation first appears, and from this point to the south end of the canal, the contractors' plant is designed primarily for rock work, just as in the preceding divisions it was designed primarily for earth excavation, and only incidentally for rock work. As stated above, the Lemont Division is in charge of Mr. H. A. Miller, Division Engineer.* We are indebted to Mr. Miller for much aid in securing the information from which the articles on Sections 2 to 8, inclusive, have been prepared.

Sections 2 and 4.

These two sections are in the hands of the well-known contracting firm of McArthur Bros., of Chicago, Ill., and for this reason, although they are separated by the mile of channel comprising Section 3, they will be described together. Originally Section 3 was in the hands of the same firm, but a dispute having arisen between the contractors and the Board of Trustees over the proper classification of certain portions of the glacial drift, it was surrendered by mutual agreement without prejudice to either party, and relet to the present contractors. Gilman & Co. In fact, all three sections, Nos. 2, 3 and 4, were readvertised at this time, but before any award was made an agreement was arrived at between McArthur Bros. and the Board of Trustees for a continuation of the work on Sections 2 and 4 at an increased price for glacial drift excavation.

We have not space to enter into a full statement of the reasons for this action, but briefly they were as follows: The Trustees readvertised Sections 2, 3 and 4, and bids were opened on Oct. 4, 1893, as follows:

	Section 2.			Section 3.			Section 4.		
	Glacial drift.	Solid rock.	Retaining wall.	Glacial drift.	Solid rock.	Retaining wall.	Glacial drift.	Solid rock.	Retaining wall.
	—cts.—		$	—cts.—		$	—cts.—		$
Christie & Lowe.	75	75	2.00	72	72	2.00	...	...	....
Dawson, Symms & Co.	45	98	2.25	45	98	2.25	47	100	2.25
McMahon & Montgomery Co.	...	...	....	..	..	....	100	250	3.50
Sinclair Cons. Co.	..	....		32	86	2.00	...	...	....
Ezekiel Smith	73	93	2.25	73	93	2.25	73	93	2.25
McKeown, Stowell & Co.	48	84	1.80	46	82	1.78	46	84	2.26
Strang & Lee.	62	90	2.00	59	85	2.00	59	90	2.00
F. H. Clement.	68	68	2.00	72	72	2.25	68	68	2.00
Winston Bros. & Stevens	..	...		70	110	3.50	..	..	....
C. C. Gilman	..	...		56	76	1.80	..	..	....
Mason, Hoge & Co.	48½	89	1.75	45	89½	1.75	49	89⅜	1.75

On Oct. 17 McArthur Bros. submitted a proposition to do the work for the following prices:

	Glacial drift.	Solid rock.	Retaining wall.
Section 2.	50 cts.	80 cts.	$1.74
" 3.	56 "	76 "	1.75
" 4.	49 "	80 "	1.87

At McArthur Bros'. prices the aggregate cost of the work on Sections 2 and 4 was several thousand dollars less than that by any of the other bids submitted. On Section 3 the prices of Gilman & Co. made the cost of the section less than did the prices of McArthur Bros. On Oct. 25 the Board of Trustees authorized McArthur Bros. to go ahead with the work on Sections 2 and 4 at the revised prices which they offered, and secured the surrender of Section 3 to Gilman & Co., as noted above. At no time during the controversy were any of the sections out of the hands of McArthur Bros., nor was work suspended by them until Section 3 was surrendered by them to Gilman & Co.

Under the original contract for Sections 2 and 4 the prices for excavating glacial drift were 28 cts. and 27 cts. per cu. yd., respectively, but with the new contract these prices were raised to 50 cts. and 49 cts. per cu. yd., respectively. About 59,000 cu. yds. of glacial drift on Section 2 and 48,500 cu. yds. on Section 4 were excavated at the original prices, which left 700,314 cu. yds. of glacial drift and 472,624 cu. yds. of solid rock on Section 2, and 957,062 cu. yds. of glacial drift and 341,020 cu. yds. of

* In the autumn of 1895 Mr. Miller resigned from his position, and the Lemont Division was placed in charge of Mr. C. L. Harrison.

solid rock on Section 4 to be excavated at 50 cts. and 49 cts. for glacial drift, and 80 cts. for solid rock. The respective costs of the two sections at the prices given above will be $922,256 and $1,022,199.

In the following description the features of the work common to both sections are given first, and then the features peculiar to each section are described under the heading of that section.

When Sections 2, 3 and 4 were put under contract the floods of the Desplaines River, which crossed and recrossed the route several times, had converted the land occupied by the proposed channel into a lake for a considerable portion of its area, while a thick growth of hardwood timber and underbrush covered the remainder of the line. The first work was therefore to lay dry the sections by the construction of levees at the most practicable points, and then to clear the timber from the right of way. That this work was a considerable undertaking is indicated by the fact that $100,000 was expended in clearing, grubbing and building levees in order to get in shape to do work on the main channel. The manner of carrying on this preliminary work is worthy of no especial note. The material for the levees was taken from the main channel where it could best be obtained, and put into the embankments by means of wheelbarrows, teams, scrapers, etc. This preliminary work was, of course, done for all three sections, and, in fact, 73,310 cu. yds. of glacial drift excavation was done on Section 3 before it was readvertised, but the remaining work described here was done on Sections 2 and 4 only.

Excavation in the main channel on Sections 2 and 4 began in August, 1892, and was prosecuted through the winter of 1892-3 until some time in July, 1893. In September, 1893, work was begun on the river diversion channels opposite these two sections, and was completed in the early part of December. During the work on the river diversion channel, and, in fact, during the entire summer of 1893, little work was done on the main channel on account of the dispute over hard material then pending. In November, 1893, excavation was begun on the main channel, and has been continued vigorously ever since.

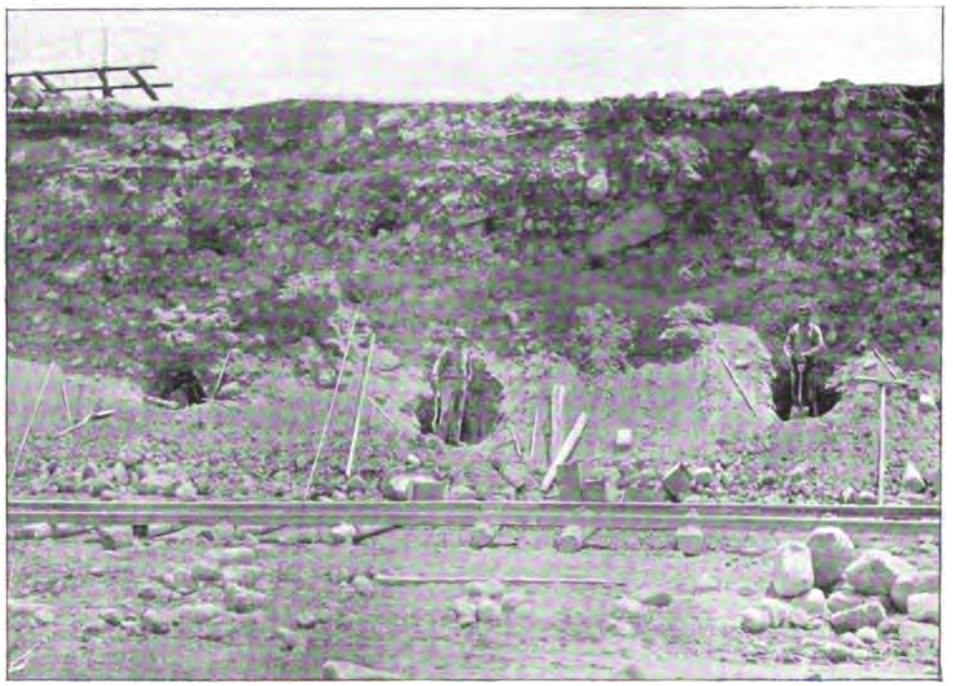


Fig. 45. View Showing Method of Blasting Cemented Gravel by Tunnels, Section 4.

During the fall and winter of 1893-4 the excavation was carried on entirely by hand, loading into 1-cu. yd. Peteler dump cars. The material on both sections after the top soil is removed is cemented gravel overlying lime rock. This cemented gravel is a glacial deposit, consisting of a mass of gravel and boulders from a few inches to 2 or 3 ft. in diameter, firmly cemented together with lime and iron. Some idea of the character of this material may be obtained from Figs. 45, 46 and 47, all of which are views of the work on Section 4. Fig. 45 shows the method of driving small tunnels into the bank for blasting, the explosive being placed at the inner ends of the tunnel. Fig. 46 shows the appearance of the bank after the blast is fired, and Fig. 47 its appearance after the steam shovel has gone through and removed the loose material. As

furnishing some further evidence regarding this material, the following extract from a letter from the contractors is given:

The nature of the material on these two sections was of so hard and difficult a character that it was questionable whether any other means than the pick and shovel and powder could remove it. The previous spring's (1893) operation with one steam shovel had seemed to demonstrate the practical inability to remove the material by such methods. However, on Section 4, one steam shovel was started to work in March, 1894, as soon as the main pumping station at that point was installed, and another one was added at the same point in April, the work on Section 2 being meanwhile prosecuted by hand-loading and small cars. In May one steam shovel was installed on Section 2, and again on June 6 another one was placed in service on this section, both being started, as was the case on Section 4, to work in opposite directions from the main pumping station, which had been installed on the section. There was a third shovel installed on this section in October, 1894.

The plan of working with the shovels has been to strip the rock by making a through cut along one side of the channel, working down the slope by a series of steps until the rock was reached. The spoil from the shovels has been conveyed out of the pit in tram cars operated by teams and cable inclines, as will be described further on.

Section 2.—Practically all of the glacial drift excavated on this section has been used in grading tracks for the traveling cableways employed in excavating the rock. To excavate the glacial drift two 70-ton Osgood excavators and one 60-ton Bucyrus special contractors' shovels have been used, loading into Peteler cars of 3 cu. yds. capacity. These cars have given unusually satisfactory service. Fig. 48 is a view of one of them. Altogether 63 are used on this section. From the shovels the cars are hauled by teams to the foot of cable inclines, thence

Fig. 46. View of Cemented Gravel After Blasting, Section 4.

Fig. 48. Peteler 3-Cu. Yd. Dump Car Used on Sections 2 and 4.

up the incline by cable, and from the top of the incline to the dump by teams. The arrangement of the tram car tracks and shovel is shown by Fig.

Fig. 47. View of Cemented Gravel After Steam Shovel Has Removed Loose Material. Section 4.

49, and Fig. 50 gives a view of one of the inclines. This particular incline is located on Sec-

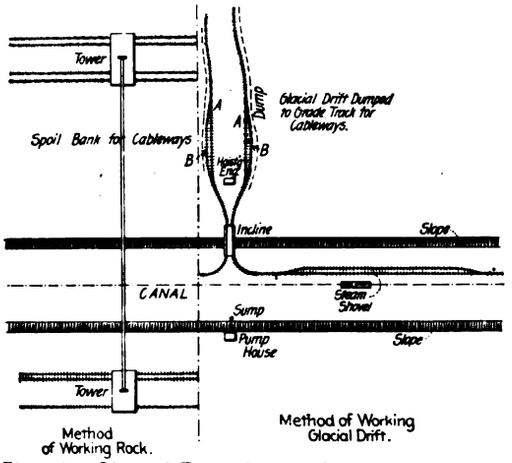


Fig. 49. Plan of Track System Showing Method of Excavation on Sections 2 and 4.

McARTHUR BROS., Chicago, Ill., Contractors.

tion 4, but it differs in no essential particular from those on Section 2.

The sketch of the car tracks and incline is a typical sketch. It will be noticed that the tracks on the dump are so arranged that the empty and loaded trains can pass each other; that is, loaded cars can be run onto track A and dumped, while empty cars are sent back to the incline by track B. The contractors have experienced no difficulty with this arrangement in keeping the shovels at all times supplied with cars. One of these inclines has handled as many as 2,500 cu. yds. per day. The inclines have been started in each case opposite the pumping stations, a cut having been excavated across the channel by hand labor, and they are moved whenever the haul becomes too great.

The hoisting plants for these inclines are all similar in character, although, of course, differing in the make and size of machinery used. They consist essentially of a hoisting engine mounted on an especially designed platform car 18 ft. wide by 40 ft. long, as shown by Fig. 51. This particular machine is a Lidgerwood 12½ × 16-in. double-drum engine, while its companion hoist is a 13 × 16-in. double-drum Webster, Camp & Lane engine. The two views, Figs. 50 and 51, show the construction and operation of the inclines very clearly. It may be stated that in addition to these main hoists for steam shovel work there are two 8 × 10-in. double-drum engines operating inclines for the 1-cu. yd. Peteler cars which are loaded by hand. There are 185 of these small cars on Section 2.

Figures obtained both from the contractors and from the engineers of the Sanitary District are available to show the work of the steam shovels on

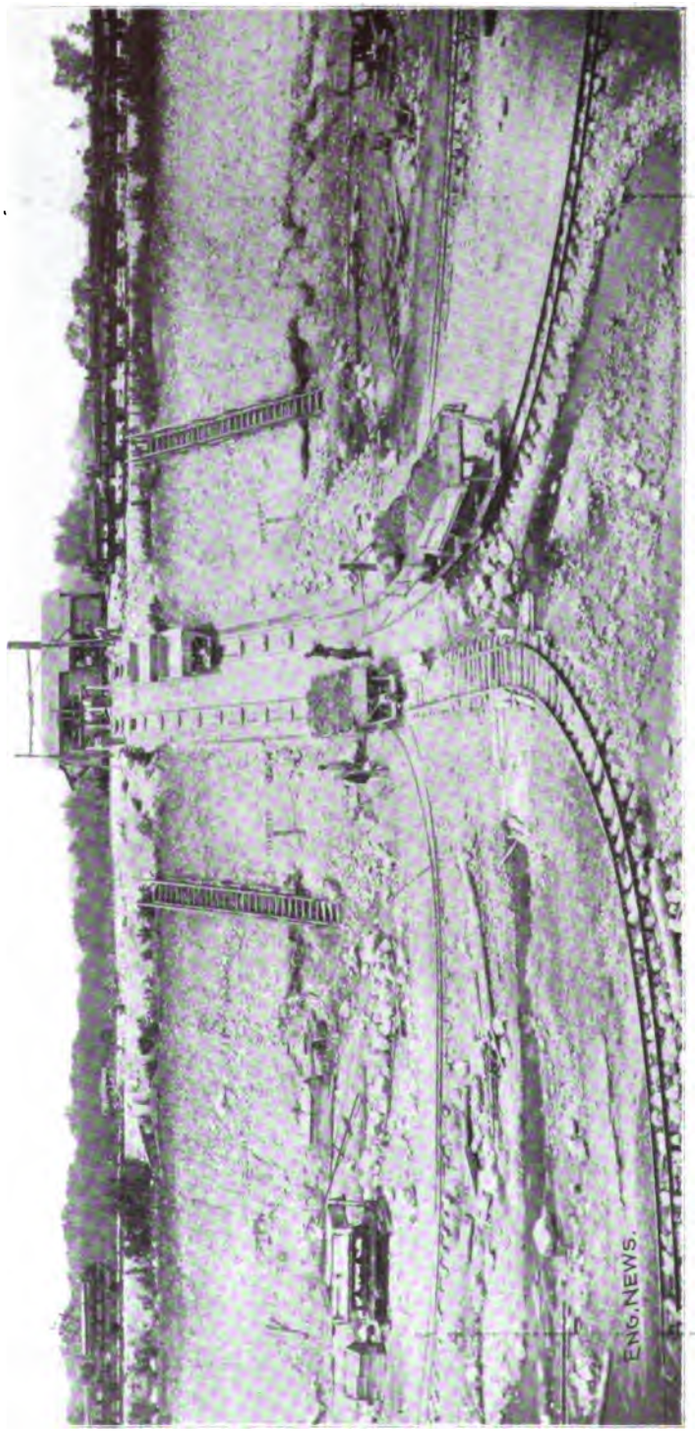


Fig. 50. Cable Incline for Hauling Glacial Drift Out of Pit, Section 4.

this section. According to the canal engineers the two Osgood shovels worked 18 and 24 ten-hour shifts in October, 1894, and handled 340 cu. yds. and 395 cu. yds. per shift, respectively, and the Bucyrus shovel worked 23 ten-hour shifts, handling 630 cu. yds. per shift. In the month of November all three shovels working together aggregated 71 shifts, and averaged 471 cu. yds. per shovel per shift.

The contractors state that the largest ten-hour day's work was done on Aug. 2, 1894, by one of the Osgood 70-ton shovels, when 1,248 cu. yds. pit measurement were handled. The largest daily-monthly average was made by the same shovel in July, 1894, and was 690 cu. yds. per day. The largest daily general average, from June 6 to Dec. 31, 1894, was also made by this shovel, and was 495 cu. yds. The general daily average of all shovels from the time of installation to Dec. 31, 1894, was 415 cu. yds.

Considering the large size of shovel employed, and also that all three were made for this heavy work, this average seems small; yet it is good average work considering the intractability of the material. That the shovel is capable of doing better work with more favorable material is shown by the statement that the big Osgood shovel has shown an (monthly average) output per day of 1,200 cu. yds., and for special daily runs has doubled this output.

The large amount of seepage water encountered on this section has required an extensive plant for draining the work. The main pumping stations are located about 1,000 ft. from each end of the section, and each is equipped with two 75-HP. boilers, one 14 × 18-in. balanced valve Erie engine, and two Heald & Sisco centrifugal pumps 12 ins. and 6 ins. in diameter. The pumps are placed at 18 ft. above the finished grade of the canal, and are operated by belts from the engine placed on the berm. These two main pumping stations have thus far been operated practically continuously, handling about 14,000,000 gallons every 24 hours, with a lift of 36 ft. In addition to the two main pumping stations there is one auxiliary station placed about the middle of the section and equipped with one 6-in. centrifugal pump; and for much of the time each shovel has been equipped with a pulsometer, to keep the shovel pit dry. These pulsometers simply pump the water out of the shovel pit to be rehandled by the main pumps. This is made necessary on account of the uneven surface of the rock, and because it was cheaper to pump the water twice than to ditch through the solid rock. As will be seen, the item of drainage is one of very considerable importance. For all pumps together 0.83 ton of coal was used per 1,000,000 gallons of water handled in 1894, and the total cost of pumping, exclusive of cost of plant,

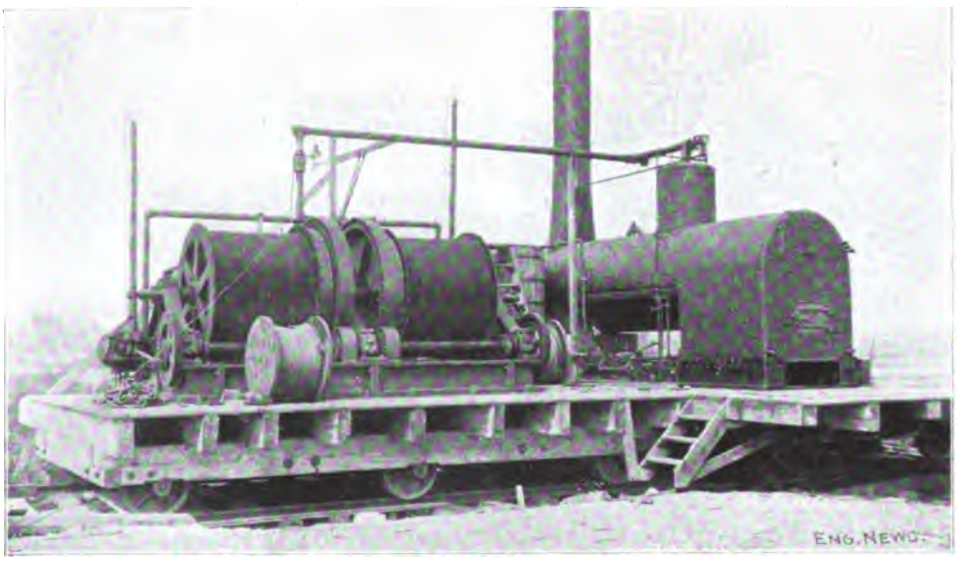


Fig. 51. Hoisting Machinery for Cable Incline.

was 2½ cts. per cu. yd. of material excavated.

For handling the rock two cableways are used, with the necessary channeling machines, rock drills, etc., to cut and blast the rock ahead. Sullivan and Ingersoll-Sergeant channeling machines and Ingersoll-Sergeant and Rand drills are used. Before taking up the work of the cableways on rock, it may be stated that during November, 1894, one cableway was worked on glacial drift for 25 ten-hour shifts, and handled 337 cu. yds. per shift.

Section 4.—The method of handling the material on this section corresponds in all essential respects to that just described for Section 2—viz., steam shovels loading into cars, teams hauling cars to foot of inclines, where they are hoisted and the spoil

wasted on the dumps. There are four steam shovels —one 70-ton Osgood, one 60-ton Bucyrus "Special Contractors'" shovel, one 45-ton Bucyrus boom type shovel and one 45-ton Bucyrus crane type shovel— and three hoisting plants, similar to those described on Section 2. The section also has two main and one auxiliary pumping stations, two cableways and the usual outfit of channelers and drills.

It may be noted at the beginning that both here and on Section 2, 750 ft. was found to be the limit of economical haul. The tracks from the foot of each incline, therefore, run 750 ft. each way, or, in other words, the glacial drift from 1,500 ft. of canal could be handled without moving the incline.

According to the reports of the engineers of the Sanitary District for October, 1894, the Osgood shovel worked 27 ten-hour shifts, handling 406 cu. yds. per shift, and the three Bucyrus shovels named above worked respectively 27, 24 and 26 shifts, and handled 760 cu. yds.. 458 cu. yds. and 480 cu. yds. In November all four shovels worked in the aggregate 103 ten-hour shifts, and each handled 490 cu. yds. per shift.

According to the contractors, the largest day's record for any shovel on this section was made on July 17, 1894, by the No. 1 boom type, 45-ton, Bucyrus shovel, and was 1,530 cu. yds. pit measurement. The largest monthly average per day was made during the same month and by the same shovel, and was 791 cu. yds. The largest general daily average for the season from the time of the installation of the shovel to Dec. 31, 1894, was made by the 60-ton Bucyrus "Special Contractors'" shovel, and was 594 cu. yds. The general daily average of all shovels for the season was 493 cu. yds. The good record made by one of the smaller shovels in comparison with the records made with the larger shovels is explained by the statement that the machine was only put into such material as it was thought best fitted to handle. Some of the material encountered on the section could not have been handled by this shovel at all. This shovel is shown in Fig. 52, which also shows the cut being made. It will be noticed that the face stands practically vertical, and that it shows very slightly the cutting marks of the dipper teeth. In other words, the action of the dipper teeth is the breaking, tearing action natural with a hard cemented gravel. It must be borne in mind, too, that the bank has been blasted, though the finished face shown in the photograph is probably somewhat beyond the limit of the blast's effect.

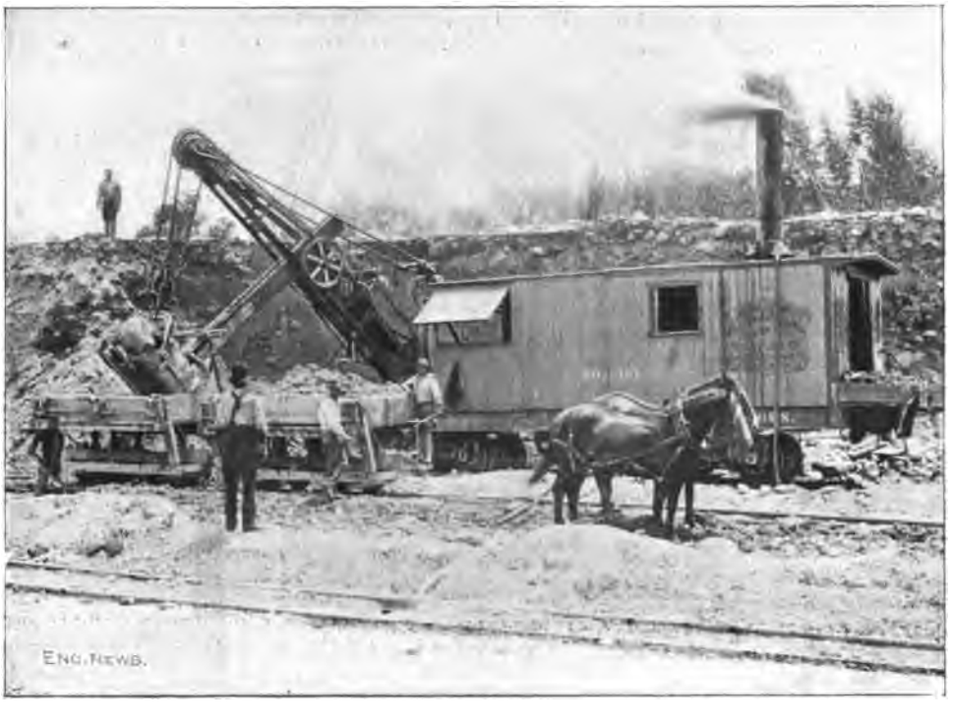


Fig. 52. Bucyrus Boom Type Excavator Loading Dump Cars, Section 4.

As has already been mentioned several times, the cemented gravel has to be blasted ahead of the shovel in order to be handled with any success at all. The method of blasting on Section 2 is to drill down from the surface with a steel bar, putting the holes down as near to the bottom as possible. This drilling has proved very difficult with the rounded pebbles and boulders, of which the material is made

up. On Section 4 the method which is generally employed is to tunnel into the face of the pit (Fig. 45) for a distance of 18 ft. to 20 ft., the workmen blasting their way in much as would be done in tunneling, and then charge the excavation with a large quantity of dynamite. The contractors state that this has proved the only effective method of handling the material.

More recent figures of the output of steam shovels in the cemented gravel of these sections give the following:

	Section 2.		Section 4.	
Month, 1895.	No. 10-hr. shifts.	Cu. yds. per shift.	No. 10-hr. shifts.	Cu. yds. per shift.
May	26	475	114	505
June	54.1	428	101.9	653
July	..	444	106	326

On Section 2 three shovels, and on Section 4 four shovels were worked.

Cableway Work.—As has just been stated, four Lidgerwood traveling cableways are used for handling the rock on Sections 2 and 4. This machine has been described in a preceding article, and in this article attention will be confined to the capacity, cost of operation, etc., of the four plants just mentioned.

The capacity of the cableways and the cost of operating them of course vary from month to month, and even from day to day; the hardness of the rock, character of the weather, efficiency of labor and superintendence, and dozens of other variables entering into the problem. This makes it very difficult to present any figures which are a reliable basis of estimate for cost and efficiency in all classes of work. It should be borne in mind, therefore, that the figures of cableway work given for Sections 2 and 4, and indeed for any other section which may be referred to in future articles, are absolutely accurate for the particular conditions there obtaining only. At the same time, by a careful comparison of controlling conditions, figures for one piece of work may be useful in estimating the cost of another piece of work.

Through the courtesy of McArthur Bros., the contractors for Sections 2 and 4, we have been furnished with some very accurate figures of the work of the four cableways employed. These figures give the cost of various items of work entering into the excavation and conveying of rock in percentages chargeable to labor and to supplies. The actual cost of the work in cents per cubic yard excavated is not given for obvious reasons.

Table II. shows the number and wages of the laborers, capacity per machine, capacity per laborer, etc., for each cableway for one month. Table III. shows percentages of cost of the various items of work which are chargeable to labor and to supplies. The tables are self-explanatory, and need not be described further. It will be noticed that the cost of "conveying," that is, taking the loaded skip to the spoil bank, dumping it, and returning it to the pit, is about from 15% to 18% of the total cost of work. This item will vary the least for different pieces of work. The cost of drilling, blasting and channeling will vary with the character of the rock; the cost of loading with the capacity of the laborers and the efficiency with which they are worked, supposing the rock to be broken to the most convenient fineness for handling at all times; the cost of pumping with the amount of seepage.

TABLE II.—Showing Amount of Rock Handled, Number of Men Employed, and Wages of Employees for Each of Four Lidgerwood Traveling Cableways at Work on Sections 2 and 4, in March, 1895.

	Section 4.		Section 2.	
	1.	2.	3.	4.
No. ten-hour shifts	49	35	52	49
" skips worked on each face.	10	10	10	10
" laborers " " " " ..	27	27	32	32
" foremen " " " " ..	2	2	2	2
Wages laborers per day	$1.50	$1.50	$1.50	$1.50
" foremen " "	3.00	3.00	3.00	3.00
" engineer " "	2.75	2.75	2.75	2.75
" fireman " "	*1.80	1.80	1.80	1.80
" towerman " "	*2.70	2.70	2.70	2.70
Total cu. yds. excavated	12,633	8,632	16,162	14,535
No. skips loaded day shifts	5,117	5,327	5,435	4,369
" " " night "	4,087	1,201	5,467	4,468
Av. load skip, cu. yds., in pl.	1.44	1.32	1.48	1.65
Cu. yds. mat'l exca. per shift.	257.8	246.6	310.8	296.6
Total hours labor	12,861	9,608	17,075	15,227
Cu. yds. exc. per man per shift	9.82	8.98	9.46	9.54
Tons coal burned per shift	1.83	1.83	2.28	2.28

* These men in every case worked 12-hour shifts, all others 10-hour shifts.

TABLE III.—Showing Percentages of Total Cost of Excavating Rock for One Month by Lidgerwood Traveling Cableways on Sections 2 and 4, Which Are Chargeable to Different Items of Work, and also the Percentages of Each Item of Work Which Are Chargeable to Labor and to Supplies.

	Section 4.						Section 2.					
Character of work.	Cableway No. 1.			Cableway No. 2.			Cableway No. 3.			Cableway No. 4.		
	Labor.	Supp's.	Total.	Labor.	Supp's.	Total.	Labor.	Supp's.	Total.	Labor.	Supp's.	Total.
Drilling	22	12.44	19.17	24.15	11.42	19.72	15.19	7.85	12.23	16.81	9.31	13.44
Blasting	2.32	54.66	20.22	3.11	59.20	22.23	3.16	50.9	22.30	2.47	49.2	20.00
Loading	47.9	2.44	32.19	43.6	.....	28.29	49.30	2.55	30.36	46.1	1.81	29.4
Conveying	15.03	20.75	16.95	14.7	18.21	15.92	13.41	22.85	17.24	15.0	22.25	17.62
Channeling	3.83	2.75	3.44	5.14	2.61	4.44	8.50	4.26	6.99	9.0	4.33	7.17
Pumping	3.16	6.76	4.25	4.15	8.55	5.87	4.12	11.59	7.09	4.21	12.10	7.32
Supt. & gen. lbr.	5.76	....	3.77	5.15	....	3.53	6.32	....	3.78	6.41	....	4.05

Later records of the cableway work in solid rock show the following results, two cableways being worked on each section:

	Section 2.		Section 4.	
Month, 1895.	No. 10-hr. shifts.	Cu. yds. per shift.	No. 10-hr. shifts.	Cu. yds. per shift.
May	90.6	319	70.7	336
June	93.6	345	56.9	374
July	..	361	63.5	302
Av. three mos.	....	341⅔	....	337⅓

The main shops, storehouses and general headquarters of the contractors for both Sections 2 and 4 are located on Section 4, where connection has

been made with the Chicago & Alton R. R. by means of a spur track. All supplies are received here and distributed to the two sections as needed. The repair shops are unusually elaborate, being equipped with engine lathes, drill presses, planers, steam hammers, and, in fact, everything necessary for doing heavy repair work. So great has been the repairs on the steam shovels, that these shops are run practically continuously night and day. In the storehouse are kept duplicate parts of all machinery in connection with the steam shovels, and a large supply of tools, iron, heavy hardware, etc., found necessary. On Section 2 there are smaller camps for the laborers and a supplementary storehouse, etc.

The cost of labor, of course, varies somewhat for different months. For the month of December, 1894, it was $2.03 per nine-hour day per man on Section 4, and $1.73 per nine-hour day per man for Section 2. The greater cost of labor on Section 4 is accounted for by the larger number of skilled workmen employed by the shops.

Section 3.

The first contract for this section was let to McArthur Brothers, of Chicago, Ill, July 20, 1892, but trouble arose between them and the Sanitary District, as has already been described in the article on Sections 2 and 4, and in the compromise agreement which followed, the section was given to Gilman & Co.

According to the latest estimates there are 417,314* cu. yds. of glacial drift, 764,358* cu. yds. of solid rock, and 13,307 cu. yds. of retaining wall on the section. Of the glacial drift 73,310 cu. yds. had been excavated by McArthur Bros., under the original contract at 27 cts. per cu. yd. The prices received by Gilman & Co. are 56 cts. per cu. yd. for glacial drift, 76 cts. per cu. yd. for solid rock, and $3.25 per cu. yd. for retaining wall. The total cost of the section is estimated from these figures as $836,769.

Work was begun by Gilman & Co. in December, 1893, and during that winter the excavation of glacial drift was prosecuted with wheelbarrows, wagons and small cars loaded by hand, it being intended as soon as spring opened to establish an excavating plant suitable to the demands of the work. This plant as finally established consisted of a system of tramcar tracks, steam shovels and inclines for taking out the glacial drift, and inclines and Lidgerwood traveling cableways for removing the rock. The general layout of the plant as it stood in December, 1894, is shown in Fig. 53.

Taking up the excavation of the glacial drift first, Fig. 53 shows the plan of operation. Having been loaded by the steam shovel, the cars are hauled in trains of two cars to the foot of the incline by horses, the tracks being always laid so that this haul is down grade. At the foot of the incline the horses are detached and the cars hauled to the top by a Mundy 60-HP. hoisting engine, with a ¾-in. rope. At the top a team is again attached and the cars are hauled to the dumping ground, and thence to the point A, where they are let down a second incline into the pit by means of a rope and snubbing post. At the bottom of the incline horses are again attached, and the cars are taken to the steam shovel. The cars are rated at 3 cu. yds. each, and are hauled in trains of two when loaded, and in trains of from four to six when empty. Of course, as the dump becomes filled the track AA has to be moved out, and in the pit similar changes are made as the shovel takes a new cut. A Victor steam shovel, built by the Toledo Foundry & Machine Co., Toledo, O., is used for filling the cars. From figures obtained from the monthly reports of progress made by the Superintendent of Construction, the following statement showing the output of this shovel for several months is abstracted:

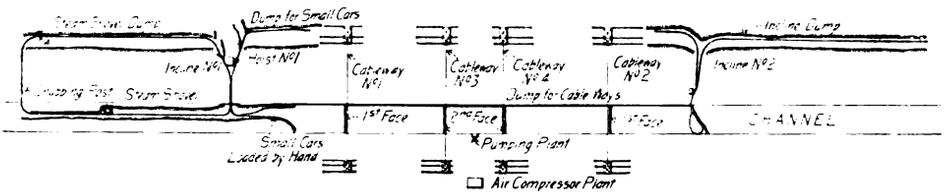


Fig. 53. Plan of Track System Showing Method of Excavation on Section 3.
GILMAN & CO., Mt. Forest, Ill., Contractors.

Month.	No. 10-hour shifts.	Cu. yds. exc. per shift.
September, 1894	21	362
October, 1894	24	316
November, 1894	18	333
December, 1894	25	392
January, 1895	17	235
May, 1895	22	296
June, 1895	21.6	380
July, 1895	21	330

In addition to the steam shovel work considerable glacial drift was excavated by hand labor, loading into small cars of 1 cu. yd. capacity, and hauling up the same incline used by the larger cars. The arrangement of the tracks for this portion of the work is clearly shown by Fig. 53. To permit of the small, narrow gage cars using the incline, a third rail was laid outside the broad gage track, and this rail and one rail of the main track used for the narrow gage track. The small cars were hauled in trains of five cars.

As a matter of novelty, it may be noted that for

* These figures are only approximate, as the glacial drift has not all been removed, and the exact surface of the rock is unknown.

a time one of the cableways designed for the rock work was put at work handling glacial drift, the skips being loaded by hand. This cableway was worked for 61 shifts in September and 56 shifts in October, and averaged 188 cu. yds. and 255 cu. yds per shift, respectively, for these two months.

Most of the rock excavation will be done by means of Lidgerwood traveling cableways, but a considerable amount of rock was also handled with an incline, as shown in Fig. 53. Cars of 1½ cu. yds capacity, working in a rock face 5 ft. deep, were used, and are stated by the contractors to have given very satisfactory service. These cars were hauled by teams and hoisting engines, as in handling glacial drift, three car trains beings used All the material excavated by means of inclines was used to grade a roadway for the cableway tracks. The output per ten-hour shift with these inclines was as follows for three months:

Month.	No. shifts.	Cu.yds. per shift.
May, 1895	25	186
June, 1895	24.6	148
July, 1895.....	15.5	20.5

The four cableways are operated so that two excavate the first lift and two the second lift; Nos. 2 and 4 working east and Nos. 1 and 3 working west from the center toward the ends of the section. These cableways are of the same general design as all the others working on the canal, with the exception of the aerial dumping device, invented by C. M. Mullinix, Supt. for Gilman & Co., which was described in the preceding article on cableways. This special form of dumping device was required on this section by the necessity of spoiling the material on both sides of the canal, and by its use the skips can be dumped on either spoil bank at will without any change in the machinery.

Fig. 54. Working Face and Cableway Excavating Rock, Section 3.

From the reports of the Superintendent of Construction, the following figures of the work of these cableways for a number of months are taken:

Month.	No. 10-hour shifts.	Cu. yds. exc. per shift.
September, 1894	126	294
October, 1894	140	267
November, 1894	153	230
December, 1894	140	305
January, 1895	173	161
May, 1895	193½	206
June, 1895	181.3	308
July, 1895	185	254

A report from the contractors covering all four cableways for the month of May, 1895, gives the following figures:

	Cableway No. 1.		Cableway No. 2.		Cableway No. 3.		Cableway No. 4.	
	Day shifts.	Night shifts.	Day shifts.	Night shifts.	Day shifts.	Night shifts.	Day shifts.	Night shifts.
No. skips handled	3,869	3,579	4,991	4,562	4,384	4,212	4,602	4,334
Cu. yds. excavated	6,031	5,727	7,985	7,298	7,012	6,740	7,361	6,935
No. hours worked	199½	195	231	219	242	237½	249	229
Cu. yds. per ten hours..	301	292	346	333	288	284	296	303

Lumping together the work of all four cableways, these figures give an average output of 305.3 cu yds. per ten-hour shift for each machine for the month. The report of the Superintendent of Construction gives this same output as 306 cu. yds per ten-hour shift. It will be noticed that the two independent records kept by the contractors and the engineers of the Sanitary District agree very closely. The contractors' figures show the average skip load to have been 1.6 cu. yds. Assuming the number of laborers worked on each face to have been regularly 36—the intended number—the average output per man per ten-hour shift for all four cableways for the month was 8.49 cu. yds.

The following table shows the number of men worked and wages paid for these same four cableways:

No. skips worked on face	9
No. laborers worked on face	36
No. foremen worked on face	1
Wages, laborers per ten-hour day	$1.50
" foreman " " " "	3.00
" firemen " " " "	1.65
" towermen " " " "	2.50
" engineer " " " "	2.75

Fig. 54 is a view showing one of the working faces and a loaded skip on its way to the spoil bank.

It should be noted that the cableways on this

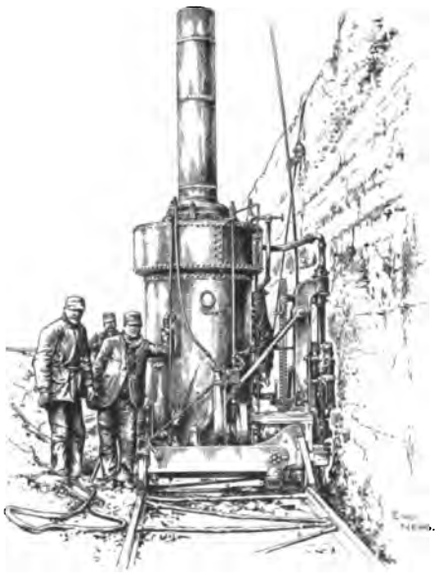


Fig. 55. Sullivan Channeler Cutting Side of Rock Channel, Section 3.

SULLIVAN MACHINERY CO., Chicago, Builders.

section are worked night and day, and that no delays are counted out, unless the men are actually laid off without pay. Both of these conditions tend to reduce the apparent daily output of the cableways. In other words, it is more economical to work day shifts only, repairing and changing machinery nights, than it is to work double shifts—day and night shifts—when time must be taken out of actual working hours to make repairs. Moreover, if all these short delays are counted out, aggregating, say, two or three hours a day, the machines show an exaggerated output per ten-hour shift, per month or year. These two methods of manipulating the records are independent of any justifiable differences in the outputs of different machines, due to favorable or unfavorable physical conditions, or good or bad management.

This point is brought up here because certain of the contractors count out all delays, while others count out only those of one-half a day duration or more. Comparisons of the figures of the output of different cableways, it will thus be seen, may lead to unfair conclusions if care is not taken to determine the exact conditions. These conditions will be given as far as possible in all articles relating to the output of the various machines on the canal, and should be considered in comparing the work of one section with another.

The channel is cut ahead of the cableways by eight Sullivan channelers, two ahead of each machine. Fig. 55 is a view of one of these channelers at work. The four channelers ahead of cableways 1 and 2 take a 12-ft. cut, and the four ahead of cableways 3 and 4 an 11-ft. cut. These machines are very extensively used all along the rock section of the channel, where a cut from a few inches to 25 ft. in depth on both sides has to be made. The variable character of the rock in which these cuts are made has necessitated unusually heavy construction for the channelers, but otherwise they require no especial mention. In future articles records of the work of some of the channeling machines used on the canal will be given.

Rand drills are used, three for each cableway face, and they receive their air from an 18 × 30-in. duplex compressor, built by the Rand Drill Co. Fig. 56 is a view of the compressor plant. A single row of holes across the canal is exploded at one shot. An instantaneous view of a blast made on this section is shown by Fig. 57. In taking this photograph the camera was placed about 200 ft. from the blast, and the time of exposure was 1-50 of a second. Nearly 2,000 lbs. of powder per day is used on the four faces.

Section 5.

The original contract for this section was let to Agnew & Co., of Chicago, Ill., July 22, 1892. On the same date the contract for Sections 6 and 7, and on July 27 the contracts for Sections 8 and 9 were let to the same firm. From the beginning the contractors showed little disposition to equip their sections with the necessary plant for economically and effectively prosecuting work of so great a magnitude, despite frequent warnings and protests by the officers of the Sanitary District. In his report of Dec. 18, 1893, the Superintendent of Construction called especial attention to the backward condition of the work on Sec-

tions 5 to 9, inclusive, and on Dec. 27, 1893, the Board of Trustees served notice upon Agnew & Co. that there had been a substantial failure on their part to comply with the requirements of the contract. This notice was given in order to lay a foundation for a notice of forfeiture, but before actual forfeiture was declared Agnew & Co. assigned their contracts to other parties, with the consent of the Board of Trustees. The contract for Section 5 was assigned to the Qualey Construction Co., which firm has carried on the work since.

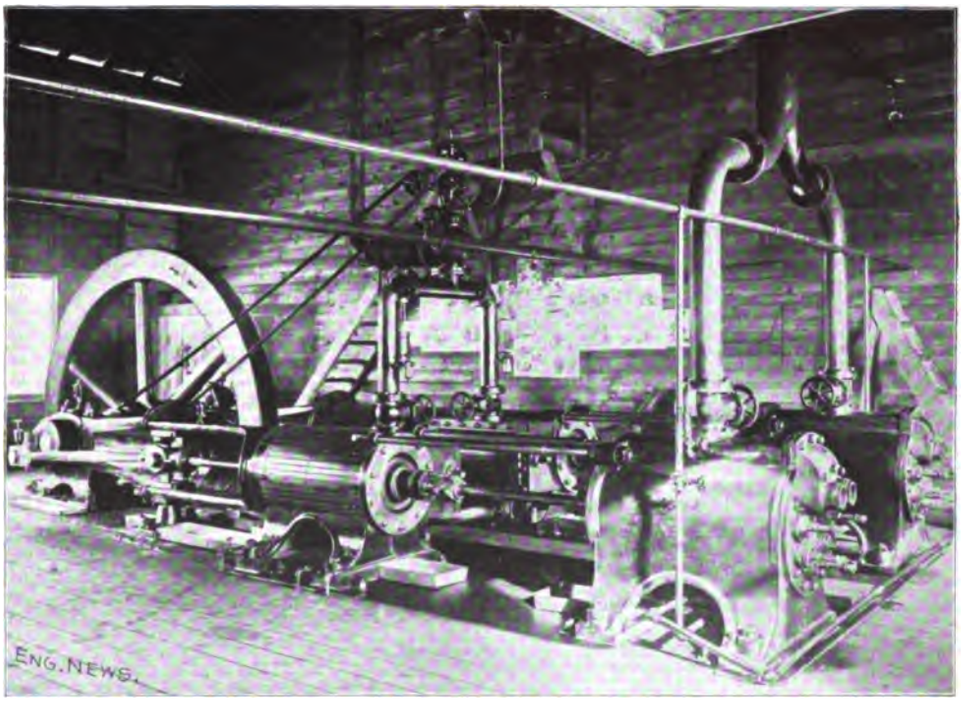


Fig. 56. Duplex 18 × 30 ins. Rand Air Compressor for Running Air Drills, Section 3.

RAND DRILL CO., New York, Builders.

According to the latest revised estimates there are 1,064,021 cu. yds. of glacial drift excavation, 265,833 cu. yds. of rock excavation and 73,424 cu. yds. of retaining wall on Section 5. The prices for this work are 27 cts. per cu. yd., 73½ cts. per cu. yd. and $3.25 per cu. yd., respectively. Steam shovels, locomotives and cars and incline hoists have been used to excavate the glacial drift, and incline hoists and a traveling cableway to excavate the rock, except that quarried for building the retaining walls. Fig. 58 is a general plan showing the arrangement of the tracks, derricks, etc., for earth and rock excavation and for building the retaining wall.

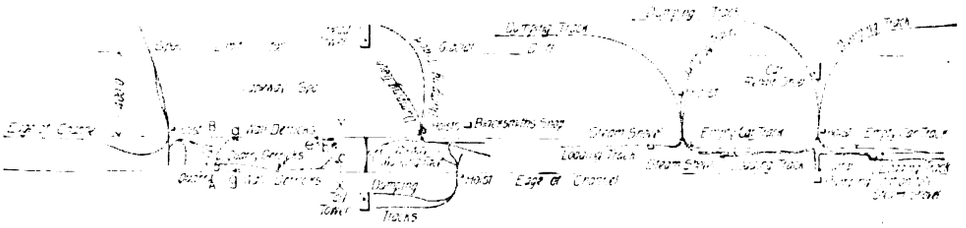


Fig. 58. Plan of Track System Showing Method of Excavation on Section 5.

THE QUALEY CONS CO., Sag Bridge, Ill., Contractors.

Taking up the glacial drift excavation first, it will be noticed that its excess over rock excavation is much greater than on either of the three sections preceding. This is due to a sudden dip in the rock which underlies Sections 4, 5 and 6, be-

Fig. 57. Instantaneous Photograph of an Atlas Powder Blast, Section 3.

Copyrighted Photograph by CHARLES STADLER, Chicago.

ginning on Section 4 and ending on Section 6, and forming a pocket filled with glacial drift. On Section 5 there is much more variation in the character of the glacial drift than on Section 4, or, indeed, on Section 6, the material varying from light loam to clay and sand, and in places to a hard conglomerate of cemented gravel and boulders. Much the larger part of the material, however, is clay overlying a softer earth, and has caused considerable trouble from slips and subsidences. In one instance a slip of the bank buried the steam shovel at work on it until only the tip of the smokestack was visible.

Three steam shovels are used to excavate the glacial drift; one Bucyrus Special Contractor's, one Bucyrus No. 1 Boom and one Barnhart's AA type. It is not possible to secure records of the work of individual shovels, but in December, 1894, and January, 1895, the No. 1 Boom and the Barnhart shovels together worked 25½ and 29 ten-hour shifts, and averaged 290 cu. yds. and 345 cu. yds. per shift, respectively, for the two months.

Later figures for May, June and July, 1895, show the output per shove. to have been 354 cu. yds., 440 cu. yds. and 348 cu. yds., respectively.

The steam shovels load into dump cars of 1½ cu. yds., 2 cu. yds. and 3 cu. yds. capacity, which are hauled to the bottoms of the inclines by small locomotives, and thence up the incline by wire ropes and hoisting engines. During the first few months of the work the locomotives hauled the cars all the way to the spoil bank, but this system was changed to the incline hoist system later. Considerable material has been taken out by hand, loading into dump cars, which are hauled to and up the inclines as just described, but no very useful records of the efficiency of this system are available.

As stated above, the solid rock on this section is being taken out by incline hoists and by a Lidgerwood cableway. The incline hoists for rock are operated much the same as those for glacial drift, the cars being loaded by hand. The cableway is operated in the manner already described for preceding sections, and calls for no special mention. According to the reports of the Superintendent of Construction, this cableway worked 20½ 10-hour shifts in December, 1894, and 9.1 shifts in

January, 1895, and took out 217 cu. yds. and 275 cu. yds. per shift, respectively, for those two months. No reports of the cableway work could be obtained from the contractors.

On Section 5, as well as on the four sections preceding, the construction of the retaining walls on each side of the channel constitutes a very considerable portion of the work. Figs. 58 and 59 show the manner of doing this part of the work. The glacial drift and top layer of solid rock are taken out as has just been described, leaving just enough rock to be excavated to build the retaining walls. The lower layer of rock is then quarried and built into the walls; the rock at each point of the channel sufficing for the walls opposite that point. It may be stated here that this convenient location of the rock is not the condition all along the retaining wall channel. On many of the sections good rock for masonry can be secured for a limited length of the section only, and this has to be transported a greater or less distance to the walls. These various conditions will be described in their proper place. The accessibility of good rock on Section 5 has, of course, simplified and cheapened the cost of retaining wall work proportionately.

The plan, Fig. 58, shows the quarry faces at AB and ZY. Close to the quarry faces are placed the quarry derricks a b c, and from each of these a track runs to one of the wall derricks, d, e, f, g, as shown. The rock is quarried in suitable dimensions, loaded onto cars by the quarry derricks, hauled to the wall derricks and lifted by them to its place in the walls. Fig. 59 shows a section of completed wall. Beginning at the middle of the section the retaining walls are carried along toward each end, the channel being practically completed as the walls are completed. From Fig. 59 some idea of the fine appearance of the retaining wall channel may be obtained.

Fig. 59. View of Section 5, Showing Quarries and Retaining Wall.

Section 6.

Like Section 5, this section was originally in the hands of Agnew & Co., but was afterwards assigned to the present contractors, Mason, Hoge & Co., early in 1894. The artificial river diversion channel, which was discontinued at the east end of Section 5, begins again at the east end of Section 6, and continues through Sections 7, 8, 9, 10 and about one-half of Section 11, a distance of about 5¾ miles. This is the longest continuous section of river diversion channel on the work. From about the middle of Section 6 to about the middle of Section 11, the old channel of the Desplaines River crossed the route of the main channel six times, and the west half of Section 6 and the east end of Section 7 were covered with the waters and mud flats of that stream.

According to the latest revised estimates, there are 803,964 cu. yds. of glacial drift excavation, 549,118 cu. yds. of solid rock excavation and 33,736 cu. yds. of retaining wall on Section 6. Of the glacial drift excavation 118,808 cu. yds. were from the river diversion channel. The price for glacial drift excavation is 27 cts. per cu. yd., for solid rock 73½ cts. per cu. yd., and for retaining wall $3.25 per cu. yd.

When Mason, Hoge & Co. assumed control of the work on Section 6 they found a hydraulic dredge working in the soft muck of the old river bed at the west end, but little else was being done. The work was not only far behind in its progress requirements, but was in such shape that the new contractors had to expend considerable time and labor to get it ready for the installation of an adequate excavating plant. The dredge work at the west end had been practically the only ef-

fective work done. This dredge had been installed by a subcontractor, Chas. Vivian & Co., under Agnew & Co., and was afterward continued at work under an agreement with the Sanitary District. By agreement Mason, Hoge & Co. assumed the contract with the dredge people when they took the section.

The dredge was a rather makeshift affair, but it did exceedingly good work. Fig. 60 is a view of this machine. The machinery was carried on a flat-bottomed barge, and housed over, as shown by the illustration. Briefly described, it consisted of a 12-in. Heald & Sisco centrifugal pump, operated by means of a belt run by a Lidgerwood hoisting engine. The boiler for this engine was horizontal and of about 80 HP. A 20-HP. boiler ran the small engine operating the cutter at the end of the ladder carrying the suction pipe. The ladder was hinged at the top to swing up and down vertically, and the barge swung back and forth on a rear spud as a pivot, power for these movements being obtained through a hand windlass.

Fig. 60. Hydraulic Suction Dredge on Section 6.

CHARLES VIVIAN & CO., Builders and Sub-contractors.

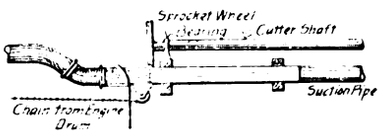


Fig. 61. Sketch Showing Manner of Applying Power to Cutter Shaft on Vivian's Dredge.

The ingenious and simple manner in which the cutter shaft was operated is worthy of notice. Ordinarily a somewhat elaborate mechanism is necessary to convey the power over the hinged joint at the top of the ladder, and still permit of free movement. The method of accomplishing this object here is shown in the accompanying sketch, Fig. 61. The cutter itself was equally simple, consisting merely of a basket-like arrangement of steel straps, as clearly shown by Fig. 60. A flexible rubber joint allowed the movement of the suction pipe. This dredge complete would have cost probably from $10,000 to $12,000, if all the machinery had been new, but as second-hand machinery was largely used the actual cost was much less.

Altogether some 240,000 cu. yds. of muck were taken out with the dredge, and its average output was from 65 to 67½ cu. yds. per hour. It will be seen that for the amount of work it had to do, the dredge was astonishingly economical and efficient. As one contractor forcibly expressed it, "Vivian went down there, and with two second-hand Lidgerwood hoisting engines and a hoop skirt on the end of a pole, took out more stuff than any other man on the canal." The price received for taking out muck with the dredge was 22 cts. per cu. yd.

Considerable material was also taken out with a power scraper designed by the same contractors, Chas. Vivian & Co. The manner of operating this scraper is shown by Fig. 62. This scraper moved material at a very large profit in the summer, but was not an economical machine in cold weather. The output was some 24 to 24½ cu. yds. per hour in summer. In the spring of 1893 this machine was reconstructed to run two scrapers side by side, but the boiler capacity was not sufficient to supply steam for both, and although both scrapers were in use, they did not often work at the same time.

The scraper was of the same shape as an ordinary drag scraper. The steam plant was on a plat-

form on the north side of the channel, back of the spoil bank, and in front of it was a wooden tower to hold the sheaves to support the cables. On the south berm there was a similar but lighter tower for the same purpose. The arrangement of the plant is clearly shown in the illustration.

There were three cables running to the scraper. One of them, cable A, was used to tip the scraper on end; cable B drew it out into the pit, and cable C hauled it out of the pit. The method of working was as follows: When the scraper had been drawn into the pit and was in the position shown in Fig. 62, cable A would be hauled in sufficiently to stand the scraper on its end, as shown in Fig. 62a. Cable C would then be hauled in, and the scraper

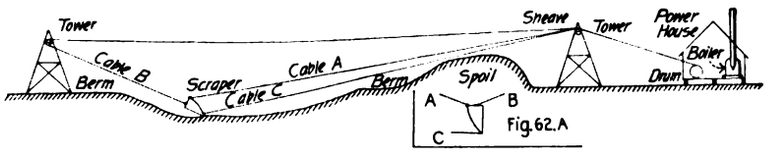


Fig. 62. Diagram Showing Manner of Operating Power Scraper on Section 6.

would fill as it resumed its original position, and would be drawn to the spoil bank. Then cable A would turn it over and drag it a few feet to empty it, after which cable B would turn it right side up again and draw it back to the position shown in Fig. 62.

The machine was not a failure, although money was lost in getting it perfected and attempting to work it in the winter, and when good weather came and the machine was perfected it had only about 50,000 cu. yds. of soft material to remove. The scraper could not move gravel or other hard material.

The work of the dredge was to cut a channel through the soft material of the old river bed, under which lay from 6 to 8 ft. of hard glacial drift covering solid rock. The muck channel had, of course, to be pumped dry before the hard glacial drift and rock could be got at, and as it was feared that the sides of the muck channel would slide into the excavation when the water was removed, it was decided to build revetments of hard material to support them. This was done with material taken from the east end of the section, as shown by the track plan, Fig. 63. Tracks were laid along the edges of the muck channel, and the hard material taken along them in cars and dumped. Fig. 64 is a view of the muck channel looking west from the levee, which shows the manner of placing the revetment. It will be understood that after placing this revetment the water was all pumped out and the remaining work was done by dry excavation, and also that the usual retaining walls were built. In other words, the revetment was a temporary support for the muck banks, although, of course, it was never removed.

In constructing the levee between the river diversion and main channels considerable trouble was also had with this muck bed. Owing to the sinking of the hard material into the muck, the levee had to be brought up to grade with additional material several different times. To prevent washouts the levee was also riprapped all along the river diversion channel side.

Turning now to the work on the east end of the section, Fig. 63 shows the system of excavation followed. The material was excavated with steam shovels and loaded into dump cars, which were hauled to the spoil banks by teams and incline hoists. Teams took the cars from the shovels to the bottoms of the inclines, where a cable was attached and they were hauled to the top by winding engines. At the top teams were again attached and took the cars to the spoil bank or to the revetment work. In the pit it will be noticed that the switches were extended along the bottom as the work proceeded. The steam shovels used were built by the Vulcan Iron Works Co., of Toledo, O., and were light traction-wheel shovels of the Little Giant type. They were worked in somewhat variable material, but generally the digging was pretty hard, although not comparing with the cemented gravel work on some of the preceding sections. According to the reports of the Superintendent of Construction, two of these shovels worked 35½ 10-hour shifts in December, 1894, and 33 10-hour shifts in January.

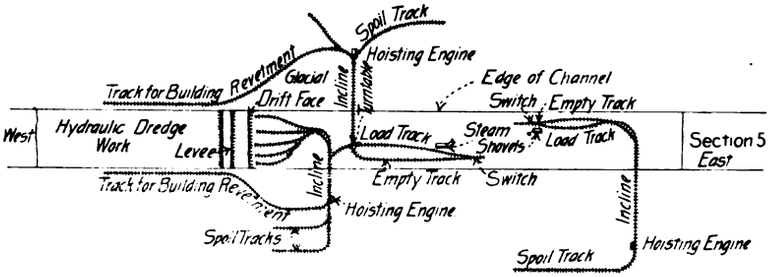


Fig. 63. Plan of Track System Showing Method of Excavation on Section 6.
MASON, HOGE & CO., Romeoville, Ill., Contractors.

1895, and averaged 360 cu. yds. and 444 cu. yds., respectively, for those two months.

The method of excavating the hard glacial drift west of the cross levee after the water had been pumped out is much the same as that adopted for the work east of the levee just described. Steam shovels load into dump cars, which are hauled to the spoil bank by teams and incline hoists. Cableways have been used to some extent for handling glacial drift, the skips being loaded by hand, and have done satisfactory service. During the months of June and July, 1895, the outputs of glacial drift per 10-hour shift per cableway were 297 cu. yds. and 571 cu. yds., respectively.

The principal work of the cableways has, however, been in handling rock. Altogether there are four cableways on the section, and, according to a report from the contractors, their output from December, 1894, to March, 1895, inclusive, was as follows:

Month.	No. shifts worked.	L'gth shift, hrs.	Delay for repairs, hrs.	Delay for skips, hrs.	Total cu. yds. excav.	Av. skip-load. cu. yds.
December	82	9	37	138	24.572	1.3
January	90	9	62	197	30,080	1.43
February	70	9	28	102	29,973	1.33
March	92	10	91	140	31,747	1.5

From these records some interesting figures are obtained, showing the average hours of delay per 10 hours of operation:

	Dec., hrs.	Jan., hrs.	Feb., hrs.	Mar., hrs.
Delay for rep'rs per 10 hrs. w'ked.	0.50	0.69	0.44	0.98
" " skips " " " "	1.87	2.21	1.62	1.52
Total delays per 10 hrs. worked.	**2.37**	**2.90**	**2.06**	**2.50**

These figures show that with cableways operating one 10-hour shift per day, each machine will lose from 30 mins. to 1 hour waiting for repairs and for skips to be loaded. Other records bear out this statement, and, in fact, show it to be too conservative. For example, on Section 7 the average delay per 10-hour shift for one cableway for three months was 1.08 hours, and on Section 8 similar figures for two cableways gave the average delay for each as 1.12 hours. With the machines working two shifts per day the delay per shift will run somewhat higher owing to not having the night hours free to make the heavier repairs.

Reducing all work to 10-hour shifts, the average output per cableway and per laborer—35 being worked to a face—per 10-hour shift were:

	Dec.	Jan.	Feb.	Mar.
Cu. yds. per shift	332.8	337.6	293	345
" " per man per shift	9.5	9.62	8.37	9.86

The records of the Superintendent of Construction give exact figures for only two of the months covered by the records furnished by the contractors, but for these two months considerable discrepancy

Fig. 64. View of Section 6, Showing Hydraulic Dredge Excavation and Revetment.

existed between the two sets of figures. The figures stand as follows:

	December. Official.	December. Contr.'s	January. Official.	January. Contr.'s
No. 10-hr. shifts w'ked.	75	73.8	79.8	89.1
Total cu. yds. excav.	23,700	24.572	29,500	30,080
Cu. yds. per 10-hr. shift.	316	332.8	370	337.6

It will be seen that the principal discrepancy exists between the figures showing the number of shifts worked, and this may have arisen in several ways, owing to the manner of keeping the records. The reliability of the figures as an exact record of work done on Section 6 is affected by this discrepancy, but for a broad generalization of the efficiency of cableway work their usefulness is not injured much. In other words, neither the contractor's nor the engineer's records give outputs differing greatly from the well-known average outputs of cableways all along the channel. Such information as is available, however, leads to the opinion that the contractor's figures of daily output for January are more likely to be correct, and the dis-

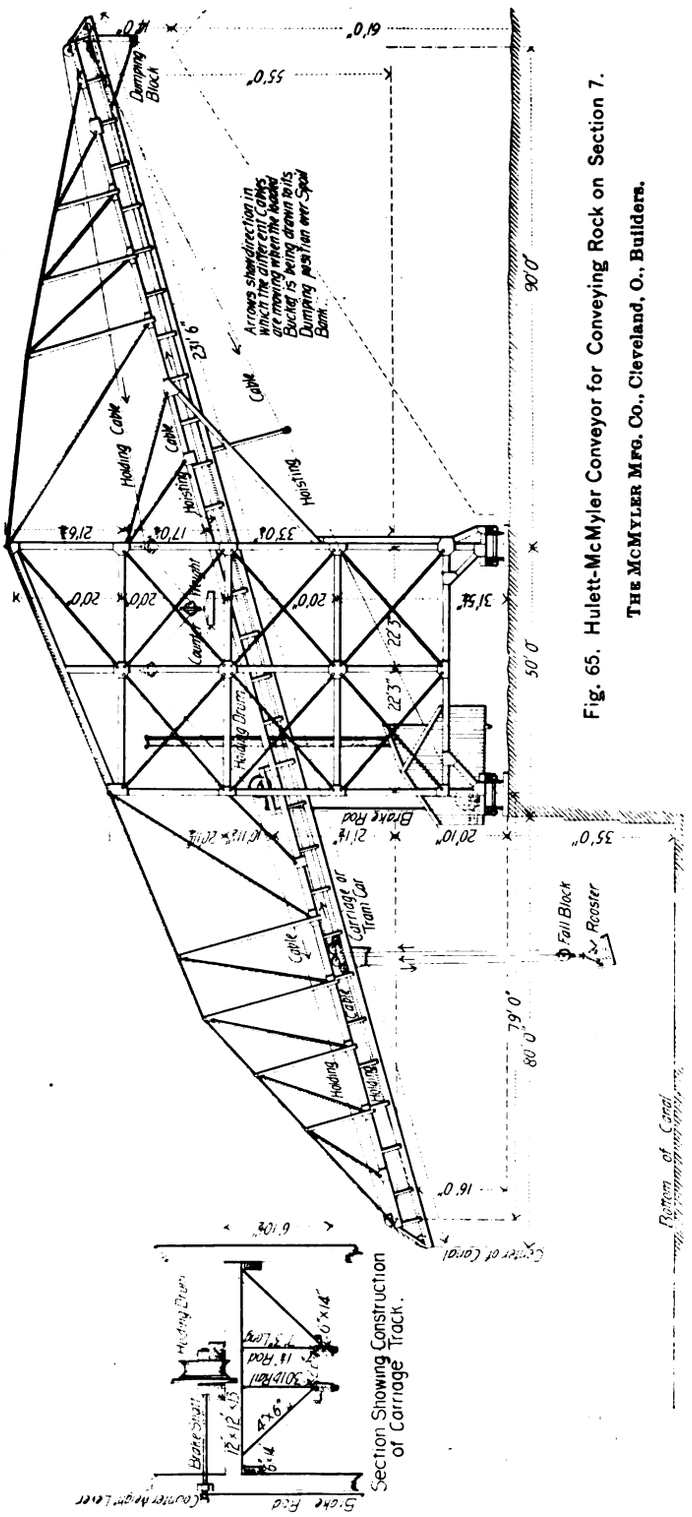


Fig. 65. Hulett-McMyler Conveyor for Conveying Rock on Section 7.

THE McMYLER MFG. CO., Cleveland, O., Builders.

crepancy shown is the greater for this month. Later figures from the records of the Superintendent of Construction, covering the months of May, June and July, 1895, show the outputs of solid rock per shift per cableway to have been for those months, respectively, 315 cu. yds., 351 cu. yds. and 218 cu. yds.

Section 7.

This section was one of the group originally in the hands of Agnew & Co., and like the other it was assigned by that firm to the present contractors. The assignment was made April 20, 1894, and the assignees were Mason, Hoge & Co. The work is actually being done by subsidiary companies organized by members of Mason, Hoge & Co. These contractors received the work greatly in arrears in its progress requirements, but have gradually cut the deficiency down to a nominal amount. According to the latest revised estimates, there are on the section 282,485 cu. yds of glacial drift excavation at 26 cts. per cu. yd.; 931,307 cu. yds. of solid rock excavation at 74½ cts. per cu. yd., and 3,957 cu. yds. of retaining wall at $3.25 per cu. yd.

As was stated in the description of Section 6, a portion of the east half of the main channel on Section 7 occupied the old bed of the Desplaines River, and when the present contractors assumed the work, they assumed a contract with Charles Vivian & Co. for removing the muck of the old river with a hydraulic dredge. The sides of the dredge excavation had to be supported by a revetment of hard material, and the levee between the main and river diversion channels had to be riprapped, as has been described on Section 6. Altogether there were 4,529 cu. yds of revetment and 4,390 cu. yds. of riprap on Section 7, costing 65 cts. and 63 cts. per cu. yd. respectively.

After removing the muck there remained only a few feet of glacial drift overlying the rock, and this was removed by dump cars and carts hauled by teams. There was nothing unusual in this part of the work, and it need not be mentioned further. The plant for rock excavation is, however, worthy of more than ordinary mention. Besides the familiar cableway there are two cantilever conveyors and two high-power revolving derricks used on the rock

work. The work of these machines will be taken up in the order named.

As the construction of the Lidgerwood traveling cableway has already been described, only the method of operation and efficiency will be considered here. It works on a face extending transversely across the channel, which is broken down by drilling rows of holes parallel with the face and blasting. About 0.75 lb. of explosive is used per cu. yd. of rock. Nine skips and about 35 men are worked on the face. The wages paid are:

Cableway engineer .....27½ cts. per hr.
" fireman .....16½ " " "
" signalmen .....10 to 15 cts. per hr.
Foreman on face .....$3 per day.
Laborers " " .....15 cts. per hr.

About 1½ tons of coal, costing $2 per ton, is burned each shift, and the cost of oil and waste is about 25 cts. per shift.

According to the reports of the Superintendent of Construction the average output of this cableway per 10-hour shift since work was begun with it has been 332 cu. yds. A report of the same machine's work obtained from the contractors and covering four months shows the following results:

Month.	Total No. skips loaded.	Total cu. yds. excavated.	Total delay, hours.	To'l No. 10-hr. shifts worked.
Dec., 1894	4,424	8,017	No. rec.	No. rec.
Jan., 1895	4,187	8,619	33	25*
Feb., 1895	4,259	7,661	28	23
Mar., 1895	7,039	11,097	14	24

* These were nine-hour shifts.

The delays noted are the aggregates of from five to twenty-minute waits for small repairs or for the buckets to be loaded, during which time the men are under pay. The average delay per 10-hour shift was 1,32 hours in January, 1.22 hours in February and 0.58 hour in March. For the three months the average delay per 10-hour shift was 1.08 hours. If the total number of shifts given above be divided into the total amount of excavation the average output per 10 hours for three months is found to be 393.9 cu. yds. Assuming that the average number of men (laborers and foremen) worked on the face was 35, then the amount of rock handled per man per 10-hour shift for three months was 10.14 cu. yds. The average skipload for the same time was 1.87 cu. yds.

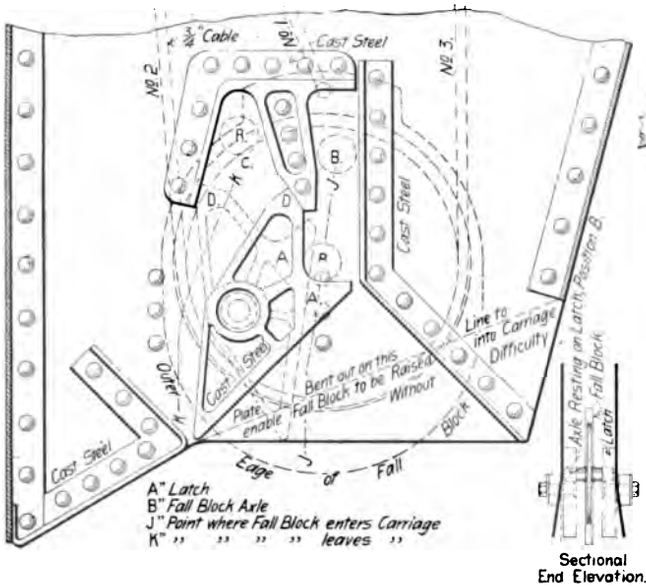


Fig. 66. Sectional Elevation of Carriage for Hulett-McMyler Conveyor.

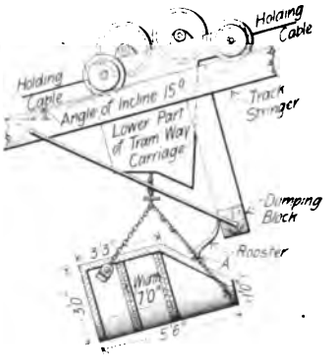


Fig. 67. Automatic Dumping Device for Hulett-McMyler Conveyor.

The second method mentioned for excavating rock is the cantilever conveyor, or Hulett-McMyler conveyor, as is known on the canal. A general elevation of this machine is shown in Fig. 65, and from this the method of construction can be easily seen. A metal framework tower is mounted on eight pairs of standard gage car wheels, and carries two cantilever arms, one of which extends upward over the spoil bank and the other downward over the channel excavation. A trolley or carriage travels along a track on the plane of the lower chord of the cantilevers, and has a fall block sus-

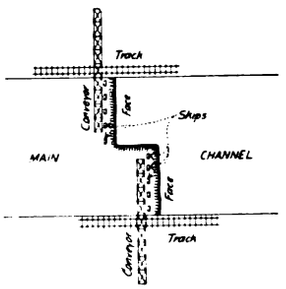


Fig. 68. Sketch Plan Showing Arrangement of Hulett-McMyler Conveyors on Section 7.

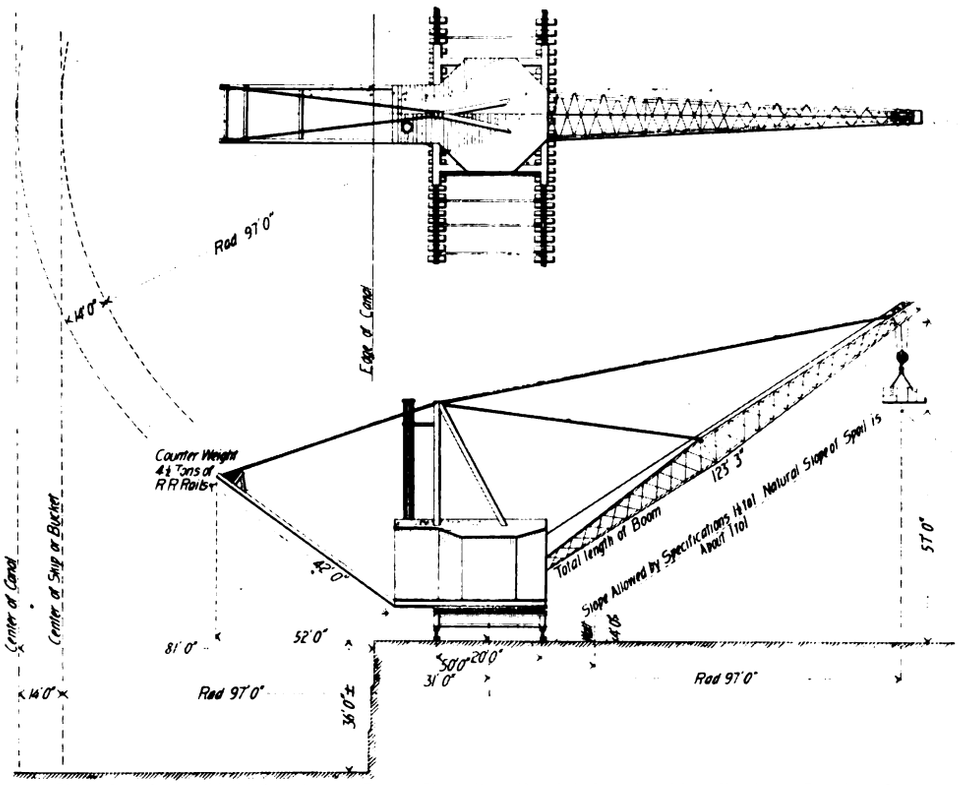


Fig. 69. Hulett-McMyler Single Boom Traveling Derrick for Handling Rock on Section 7.

THE McMYLER MFG. Co., Cleveland, O., Builders.

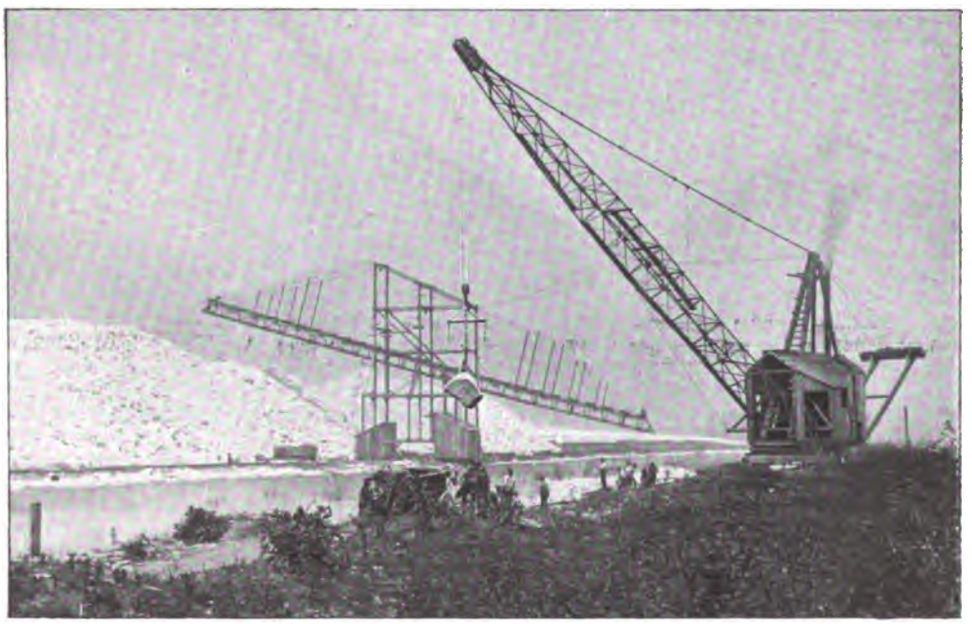


Fig. 70. View Showing Hulett-McMyler Derricks and Conveyors on Section 7.

pended from it, which carries the skip. Referring to the illustration, Fig. 65, it will be seen that the fall block and attached skip are hauled vertically to the carriage, to which it is locked automatically, and then the carriage and skip are moved along the track until they overhang the spoil bank, when pit. The next move is to lower the fall block and skip to the bottom of the pit. First the fall block is hoisted so that the axle strikes the latch and forces it to the position shown by the broken lines. When the axle reaches the position R the latch returns to its normal position. The fall block is

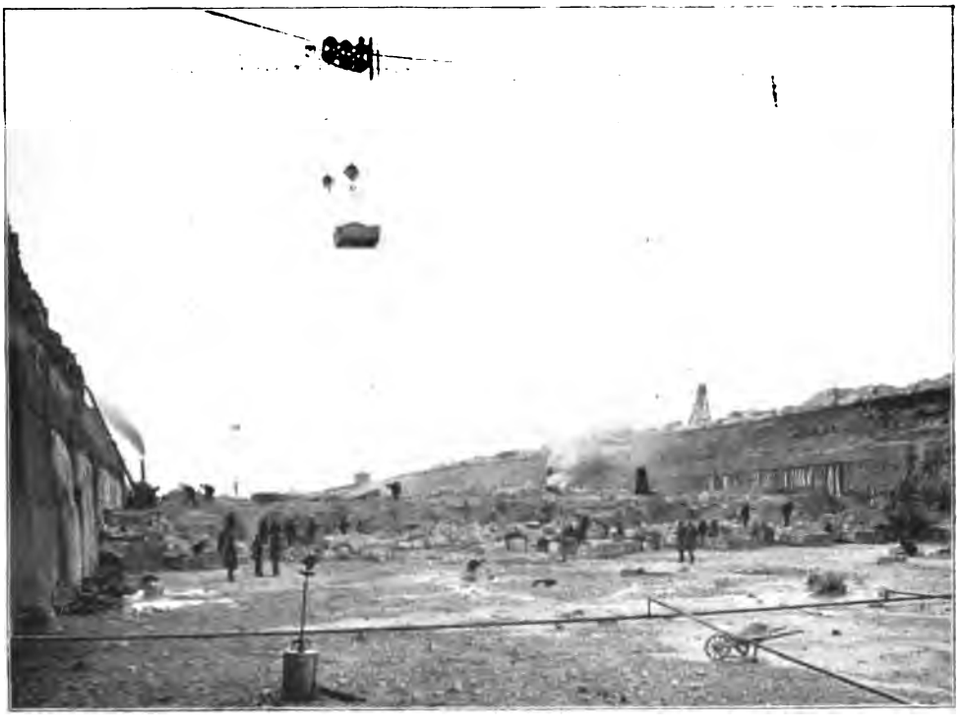


Fig. 71. View of Cableway Work on Section 8.

MASON, HOGE & CO., Romeoville, Ill, Contractors.

the skip is automatically dumped. The carriage is held at any point desired by the holding rope, whose function and operation are plainly shown by the drawing. The carriage and fall block are operated by a 9 × 12-in. hoisting engine, working under 80 lbs. steam pressure and making 200 revolutions per minute.

The only features about this conveyor which need especial explanation are the automatic locking device in the carriage and the automatic dumping device. Fig. 66 is a sectional elevation of the carriage. The cast steel latch, A, is shown in its normal position by the full lines. When the fall block with the bucket attached is hoisted from the pit the axle strikes the lower inclined face of the latch and forces it into the position shown by the broken lines, allowing the axle to pass to the position B. The latch now falls back to its normal position and the fall block is lowered until the axle rests on the notch at P, where it remains until the carriage is hauled to the upper end of the cantilever, dumped, and returned to its position over the then lowered, the axle passing along the line KK, until the skip rests on the bottom of the pit. The line J J shows the route of the axle when entering the carriage.

The arrangement for automatically dumping the skip is shown by Fig. 67 and is very simple. The carriage is drawn up the cantilever until the "rooster" strikes the dumping block and is forced back, releasing the hook A. This allows the open end of the skip to drop and the load to spill out. It will be seen that the bucket may be dumped at any point on the conveyor by simply placing the dumping block at that point. The skip is of steel, and has a capacity of 3.7 cu. yds. water measure, or 1⅝ cu. yds. of rock in place. This last figure is calculated from the engineer's estimates of excavation done, and the number of skip loads covered by that quantity. The total weight of the conveyor is 110 tons, and its cost is between $7,500 and $10,000.

Two of these conveyors are used on Section 7, one on each side of the canal, and they are placed nearly opposite each other. Fig. 68 is a sketch

plan showing the arrangement. Each conveyor works a face one-half the width of the channel, with five skips and from 25 to 30 men in the pit. Three of these men attach the skips to the fall block and the others load the skips. Two men—an engineer and fireman—are required to operate each conveyor, and these men receive $2.50 and $1.50 per 10-hour day, respectively. The other expenses of operating each conveyor per 10-hour shift are approximately as follows: Services of machinist, $1; superintendence, 75 cts.; coal, 1¼ tons, $2.20; oil, water and waste, 25 cts.; repairs, 50 cts.; maintenance of track, $1.50; services of night watchman, 50 cts.; making a total of $10.70 per 10-hour day. It is not easy to get exact figures of expenses, but these have been carefully verified wherever possible, and are believed to be approximately accurate as far as they go. The amount of rock taken out by these conveyors, of course, varies from day to day, but according to the reports of the Superintendent of Construction the average amount per 10-hour shift since the two conveyors have been at work on Section 7 is 190 cu. yds. This record extends over several months' time. The highest daily record made up to Feb. 15, 1895, was 367 cu. yds. These figures, it will be understood, indicate the capacity of the men loading the skips rather than the capacity of the conveyor to handle the loaded skips, but they are the figures which interest the contractor. What the conveyor might do if the skips were loaded as fast as it could handle them is another thing.

The conveyors just described were built by the Hulett-McMyler Mfg. Co., of Cleveland, O., as were also the two high-power derricks on Section 7. An elevation and plan of one of the Hulett-McMyler derricks are shown in Fig. 69, and the other is identically the same in construction and operation. The derrick has a single boom 123¼ ft. long, properly counterbalanced and mounted on a turntable, the whole being carried by a 20-ft. gage car. The extreme radius of swing of the bucket is 97 ft. This derrick has the longest boom of any single-boom self-contained derrick* on the canal, and, so far as we know of, any ever used anywhere.

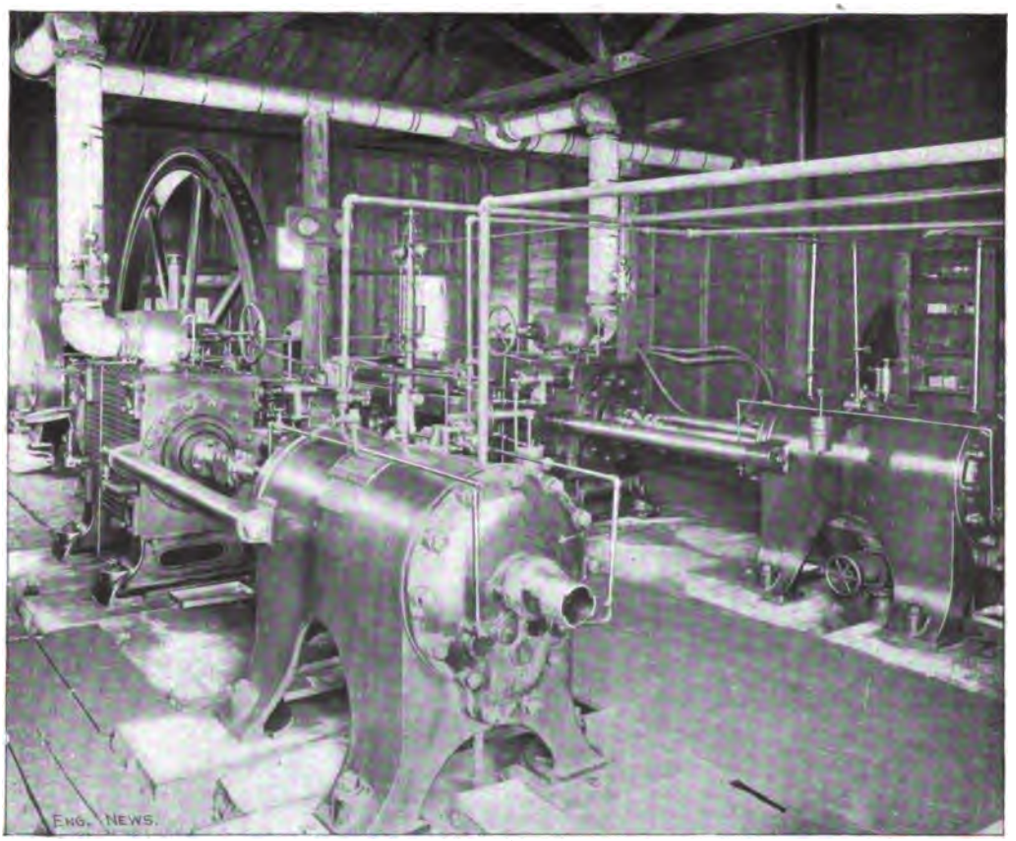


Fig. 72. Ingersoll-Sergeant 18 x 20 1-2 x 36 in. Duplex Corliss Air Compressor Plant, Section 8.
THE INGERSOLL-SERGEANT DRILL CO., New York, Builders.

* The double-boom self-contained derricks on Section 14 of the Drainage Canal are larger, but this does not alter the truth of the statement about the Hulett-McMyler derricks, which are self-contained single-boom counter-balanced derricks.

The manner of bracing the boom to the turn table is clearly shown by the drawings. All movements, both turning, traveling and hoisting, are controlled by four levers. It is stated that the

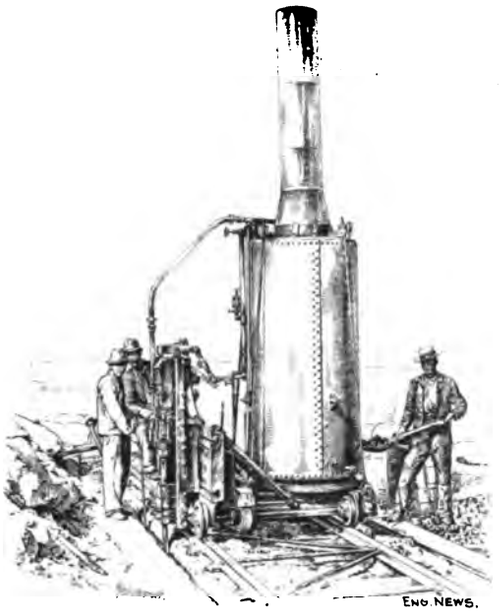


Fig. 73. The Ingersoll-Sergeant Channeling Machine.
THE INGERSOLL-SERGEANT DRILL CO., Builders.

derrick will swing its skip from the pit to the spoil bank, dump the load, and return to the pit in 45 seconds. The rate of travel along the track is 400 ft. per minute. The skip is of steel and has a capacity of 4 cu. yds. water measure, or of 1⅝ cu yds. of rock in place. The total weight of the skip is 2,400 lbs., and of the full load, 1⅝ cu. yds., 3½ tons. The safe working load of the machine is 10,000 lbs.

The method of operation is to place one derrick on each side of the channel, nearly opposite the other. In this position each derrick takes out one-half the rock. Three men—a cranesman, fireman and a man to trip the skips—are required to operate each derrick. The two derricks operate a face clear across the channel, with 12 skips, 2 foremen and 50 laborers. Six laborers, or three for each derrick, attach and detach the skips. The skip is dumped by an ordinary rope trip. According to figures collected by Mr. Wm. M. Christie, while on the Division Engineer's staff at Lemont, the total cost of operating one of these derricks, including wages, coal, oil and waste, repairs, etc., is $10 per 10-hour shift. About one ton of coal is burned by each derrick each shift. The total weight of the derrick is 95 tons, and the total cost about $15,000.

Figures taken from the reports of the Superintendent of Construction show the output of these derricks since they began work to be 219 cu. yds. per 10-hour shift each. It is stated that the two derricks together have taken out as much as 894 cu. yds. per 10-hour shift. These quantities are rock in place. Fig. 70 is a view showing one conveyor and one derrick at work on the channel.

Turning now to some of the general features of the rock work; considerable rock on the top was taken out with dump cars. These were loaded by hand and hauled by team to the bottoms of the inclines, up which they were drawn by hoisting engines, and then hauled by team to the dumping ground. This rock was used to grade tracks for the conveyors, derricks and cableways, and for riprap. Seventy-seven thousand two hundred cu. yds. of rock suitable for dimension stone have been quarried by the plug and feather method, an extra of $1 per cu. yd. being allowed to the contractor for the work of quarrying and storing the

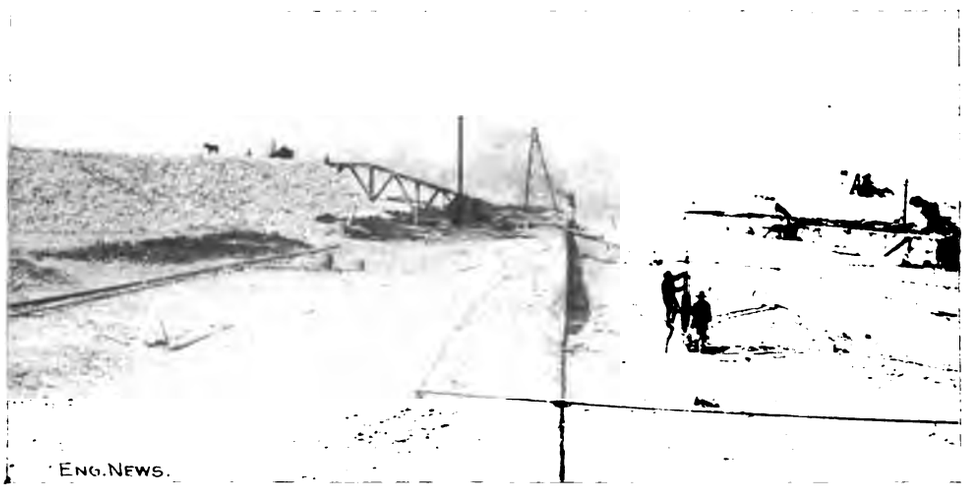


Fig. 74. View of Section 8 Showing Cut Made by Channeling Machine.

stone. The stone is stored on the bank of the main channel, and it is expected that it will be used in bridge piers or retaining walls on other sections. Most of the retaining wall on this section was built to bring the sides of the channel up to grade, the top layer of rock being rotten, and to fill in pockets of soft rock.

Sullivan and Ingersoll-Sergeant steam channelers are used, and both Ingersoll-Sergeant and Rand air drills. These receive their air from a 20 × 30-in. duplex Rand compressor, which forces the air into a 4-ft. × 5-ft. cylindrical receiver, from which it enters the pipe line running along the canal berm. This pipe reduces from 8 ins. in diameter at the receiver to 7 ins., 6 ins., 4 ins. and 3 ins., and has 2½-in. branches at various points for connecting the 1¼-in. air hose to the drills.

Section 8.

The original contractors for this section were Agnew & Co., who assigned the work to Mason, Hoge, King & Co., Jan. 17, 1894. When these contractors took the work it was greatly in arrears in its monthly progress requirements, but this delinquency was rapidly overcome when an adequate excavating plant had been established, and work was vigorously pushed.

According to the latest estimates there are on this section 101,443 cu. yds. of glacial drift excavation at 26 cts. per cu. yd., 1,262,749 cu. yds. of solid rock at 74¾ cts. per cu. yd. and 3,957 cu. yds of retaining wall at $3.25 per cu. yd. Of the glacial drift excavation 57,867 cu. yds. were in the river diversion channel. Practically all of the glacial drift on the main channel consisted of a thin layer of soil over the rock surface, which was removed by teams and hand labor. The solid rock has been handled with five traveling cableways and from two to three cable inclines. With these devices 579,500 cu. yds. of rock were excavated in 1894. The average daily labor force and plant worked during the same 12 months was:

Men	351¼
Teams	15.6
Pumps	5.4
Cable inclines	1.8
Air-drills	13.
Air-compressors	0.96
Channelers	7.
Cableways	3.85
Tram-cars	17.4

The largest monthly output during 1894 was 76,200 cu. yds. in July, working an average of 544 men, 20 teams, 18.1 drills, 2.7 inclines, 10.9 channelers, 5 cableways and 28 cars per day.

A pretty comprehensive view of the work on Section 8 is given by Fig. 71, which is a view looking east. The method of operating the cableways does not differ from that described for preceding sections. A face extending across the channel is worked, the rock being blasted down and loaded by hand. A row of 20 holes is put in 8 ft. back from the face and 8 ft. apart, and each hole is loaded with about 15 lbs. of dynamite. Rand air drills are used, and are supplied with power by an Ingersoll-Sergeant duplex Corliss air compressor, with 16 × 36-in. steam and 20½ × 36-in. air cylinders. This machine pumps into a receiver from which an 8-in. pipe leads to the work. As the compressor plant (Fig. 72) is located near the center of the section, pipes extend both up and down the line. The diameter of the pipe is, of course, reduced as the distance from the compressor increases. The boiler plant consists of three 100-HP., 66-in. × 16-ft. tubular boilers.

The view Fig. 71 shows two faces, each worked by a separate cableway. Nine skips and 40 men are employed on each face. The wages paid are as follows:

Foreman, per day	$3
Engineman, per hour	27½ cts.
Fireman, per hour	16½ "
Signalman, " "	10 to 15 "
Laborers, " "	15 "

About 1½ tons of coal, costing $2 per ton, are used by each cableway per 10-hour shift, and the cost of oil and waste per shift is about 25 cts. for each machine.

As stated above, five cableways have been worked. Two of these are operated by Locher, Harder & Williamson, subcontractors, and three by Mason & King. Locher, Harder & Williamson have furnished the following records of the two cableways operated by them for the first three months of 1895.

	No. skips handled by Cableway No. 1.	No. skips handled by Cable'y No. 2.	Both cable'ys.	Total cu. yds. excav.	Total delay, hrs.	Total shifts wkd.
Jan.	5,327	5,158	10,485	17,475	80	37*
Feb.	3,742	3,127	6,869	14,809	63	30*
Mar.	5,756	2,424	8,180	13,491	64	30½

* January, all nine-hour shifts; February, 15 ten-hour and 15 nine-hour shifts worked.

According to these figures the output per cableway per hour for January was 52½ cu. yds., for February, 51.9 cu. yds., and for March, 44.2 cu. yds. These outputs are so much greater than any previously recorded as to place some doubt on the reliability of the figures. Unfortunately the published records of the Superintendent of Construction give detailed figures of cableway work on this section only for the month of January. The figures for this month show that five cableways worked 99.2 days and excavated 41,400 cu. yds., or 417 cu. yds. per day. Assuming that the 99.2 "days" reported by the Superintendent of Construction mean 99.2 nine-hour day shifts, which was the practice of the contractors during that month, and assuming the figures given above for two of the cableways are accurate, then for the three other cableways we have:

	No. shifts worked.	Total cu. yds.	Cu. yds. per shift.
All five cableways	99.2	41,400	417
Two cableways reported	37	17,475	472.2
Three cableways remaining	62.2	23,925	384

The two cableways operated by Locher, Harder & Williamson took out 88 cu. yds. more per day each than did the three cableways operated by Mason & King. In other words, if both the contractors' and engineers' figures are correct, the output per hour recorded above is not a fair record of cableway work on Section 8 for January, 1895.

Turning again to the report of operations for Jan-

uary, it will be seen that the two cableways reported worked 18½ nine-hour day shifts each during that month. The total number of working days in January, 1895, was 26. The character of the rock and face worked on Section 8 are probably more favorable for cableway work than on any other section of the channel where this machine is used. Both the small number of shifts worked and the favorable physical conditions are favorable to a large output per cableway per shift.

These points are brought out here for the purpose of emphasizing the danger of drawing, as we know has been done, any broad conclusions from figures covering but one set of conditions. A considerable period of operation and a wide variation in the conditions of work are necessary for the evolution of any reliable constant for calculating the efficiency of cableways in handling rock. For example, the reports of the Superintendent of Construction give 417 cu. yds. as the average daily output of each cableway on Section 8 for January, 1895, but for the entire period during which these same cableways were worked in 1894 he gave the average daily output of 357 cu. yds. On Section 7 the average daily output for 1894 was 300 cu. yds., and on Section 6, 222 cu. yds. On Sections 2 to 5, inclusive, the averages will run about like those on Sections 6 and 7. It now seems very probable that the average output will run higher during 1895, since all the labor of working out good faces and getting work systematized has been for the most part completed.

The channeling on Section 8 has been done by Ingersoll-Sergeant and Sullivan channelers. Fig. 73 shows one of the Ingersoll-Sergeant channelers at work. In Chapter XII. the work of the Ingersoll-Sergeant machines on Section 8 is given in some detail. Fig. 74 shows a cut made by one of the channelers and other easily recognized features of the work on Section 8.

The Lidgerwood Mfg. Co. has submitted to us the following statement requesting that it be appended to the records of cableway work given in this chapter:

Output.

Section 2.—The small average skip load and the small number of laborers employed, as shown in the table given, tend to reduce very much the output which is recorded in the same table.

Section 3.—The rock is very hard and a good many large stones are chained out, both of which facts tend to reduce the comparative capacity but not the real efficiency.

Section 5.—The cableway has been used much of the time in cleaning off the top rock to expose suitable quarry stone, and also for cleaning up the bottom, both of which uses made a low face, and a large output is not possible under this condition.

Section 6.—The rock breaks up in larger pieces than on Section 8. It is, therefore, more difficult to load into the skips and less material per day can be handled. In proof of this statement, we have found that the average load per skip on Section 6 is only 1.4 cu. yds., while on Section 8 it is 1.8 cu. yds., on a basis of 150,000 cu. yds. Section 6 has also experienced more difficulty from water in the pit and from irregular faces and ledges.

It is generally understood that on the lower sections the character of the rock is much more favorable for a large output per day than on the sections further east, where the cableways have been for the most part employed. Compared with previous performances of the cableway, the summer of 1895 has not shown the higher records that was expected as a result of warm weather work, as compared with winter work, for several reasons. The most important reasons are: (1) A good deal of work done during the summer was upon the bottom lift. This means that much time was required for cleaning up the bottom, and, in many instances, that the face was too low to render a large output possible. (2) The increased demand for labor among the steel interests of Chicago made a scarcity of labor on some sections of the canal.

Section 8.—The comments on the Locher, Harder & Williamson records are hardly fair, as they appear to cast a reflection on the integrity of the records given. Referring to the statement that "these records are so much greater than any previously recorded as to place some doubt on the reliability of the figures," it is only necessary to refer to the "Proceedings of the Sanitary District," p. 2499, in which the record for December, 1894, is given as follows: "The five cableways worked a total of 93 days, making the excellent daily average of 496 cu. yds. each." (The sentence immediately succeeding says: "Their average since starting up is 357 cu. yds. per day."—Ed.) If Locher, Harder & Williamson, for any special reasons, have been enabled to make better records in the month mentioned in the article than Mason & King, we cannot see why the records are not perfectly fair. (They are fair as far as we know for the two cableways and the particular period referred to, but not fair for all five cableways for this period, since the three cableways operated by Mason & King took out fewer cubic yards of rock per shift. In calculating the efficiency in output of cableways on Section 8, the outputs of all five cableways must be considered, and not the outputs alone of the two cableways which did the best work.—Ed.) There are several reasons why such a difference might occur. For instance, taking the two cableways of Locher, Harder & Williamson, one was working on the second lift, the other was working on the third lift, and owing to the hardness of the rock and the increase of the depth, the cableway on the third lift showed records considerably smaller than did the one on the second lift. Another point is that Locher, Harder & Williamson kept exact records of the time run and their output is reduced to the actual number of shifts worked, while we understand that Mason & King do not take into consideration the delays, the aggregate of which would amount to considerable on three machines. Mason & King may have been delayed by accident of one kind or another. Although the figures given by Engineering News, with reference to Section 8, are substantially correct, it seems as if the notes on them and the conclusions drawn are somewhat severe.

Delays.

Section 6.—It should be emphasized that the total delays given in the tables are for four cableways. It is not fair to say that the delay due to the cableway is from 30 min. to 1 hr., for the reasons that this delay is made up of two different items: (1) Delay for repairs to the cableway, and (2) delay due to there being water in the pit, or to there being no rock to handle, or on

account of the drilling or blasting, or on account of the character of the ledge. The first delay which is chargeable directly to the cableway itself is generally but a quarter of the entire delay; the other three-quarters are delays for which the cableway is in no way responsible. As proving the accuracy of the above statements, we submit the following records of delays on Section 7, for February, 1895:

		Delay, mins.
Feb. 2.	Door ring leaked during night and boiler had to be refilled	45
Feb. 13.	Bolt broke in dumping device	30
Feb. 15.	Main cable sheave broke at 9 a. m., and was replaced in 1 hr., but men left pit until after noon	180
Feb. 18.	Dump line broke; replaced in 1 hr., but men left pit	90
Feb. 21.	Endless dump and hoist ropes tangled	120
Feb. 26.	Boxing for endless tail tower sheave broke and men left pit	180
Feb. 28.	Button line broke	120
	Total delays due to cableway..12 hrs. 45 min.	

During this same month 16 hrs. 6 mins. were lost in waiting on the mucking contractors, making the total delay 28 hrs. 51 mins.

In addition to the above losses of time, the cableway was idle from Feb. 5 to Feb. 9, inclusive, all working days, during which time the machine had to be moved to allow the passage of a McMyler derrick, which was being taken to another part of the section. In the month there were 24 working days, of which the cableway worked only 19 shifts, or 190 hrs. If we take the actual time run we have only 190 hrs. minus 28 hrs. 51 mins. or 161 hrs. 9 mins. for the time actually run. The average output was 403 cu. yds. per shift worked, or 476 cu. yds. per ten hours actually run.

For the month of March, 1895, on Section 7, there were 7½ hrs. delay due to the cableway and 10 hrs. 55 mins. due to the mucking contractor, or a total of 18 hrs. 25 mins. delay. The output per shift worked was 462.4 cu. yds. and per ten hours actually run, about 500 cu. yds.

A comparison of the above statements with the articles in question will show that the discrepancy is more apparent than real. In referring to the first cableway work mentioned (Sections 2 and 4, the following statement was made: "The capacity of cableways and the cost of operating them of course may vary from month to month, and even from day to day, the hardness of the rock, character of the weather, efficiency of labor and superintendence, and dozens of other variables entering into the problem. It should be borne in mind, therefore, that the figures of cableway work given for Sections 2 and 4, and indeed for any other section, are absolutely accurate for the particular conditions there obtaining only." The information given above by the Lidgerwood Mfg. Co. substantiates the accuracy of this statement.

In reference to the record of delays on Section 6, the article divides the delays into two classes, (1) delays for repairs, (2) delays waiting on skips, on exactly the same basis as is done above by the Lidgerwood Mfg. Co., and the conclusions drawn are substantially the same.

CHAPTER X.

BROWN CANTILEVER CRANES.

NEXT to the traveling cableway the special machine used in the greatest numbers for conveying rock on the drainage canal is the cantilever crane manufactured by the Brown Hoisting & Conveying Machine Co., of Cleveland, O. As is well known, this machine has been built by this company for years for conveying coal, ore, pig iron and other heavy material, and it was argued that with some modifications it could be efficiently applied to the canal work. The work which the machines have done is proof of the soundness of these arguments, for they have far exceeded the requirements specified. When the contractors of different sections agreed to use the cranes, they stated that 225 loads per day, or about 390 cu. yds. of rock in place, would be a more than satisfactory output. In records of work which will be given in future articles, it will be seen that the machines have accomplished all they were called upon to do.

Altogether eleven cantilever cranes have been used on the canal—three on Section 10 and eight divided between Sections 11, 12 and 13. As all the machines are practically identical in construction, a description of one on Section 10 will answer for all, but the method of operation and outputs of the different machines will be described in connection with the section on which they work.

Fig. 75 is a plan and elevation of one of the canal cranes, showing its location in respect to the channel and spoil bank when in operation, and Fig. 76 is a view of the same machine, showing a piece of completed rock cut, and the face upon which work is being prosecuted. As will be seen from the drawings, the crane consists of two connected cantilevers supported on a tower arranged to travel on a track on the berm. The cantilever trusses have an inclination of 12½°, so that one arm of the crane projects downward over the channel, while the other projects upward over the spoil bank. From end to end the trusses are 355 ft. long generally, but in some machines this length is 353 ft. In all machines the height is sufficient to allow an 80-ft. spoil bank.

Fig. 76. View of Brown Cantilever Crane and Working Face in Rock Excavation.

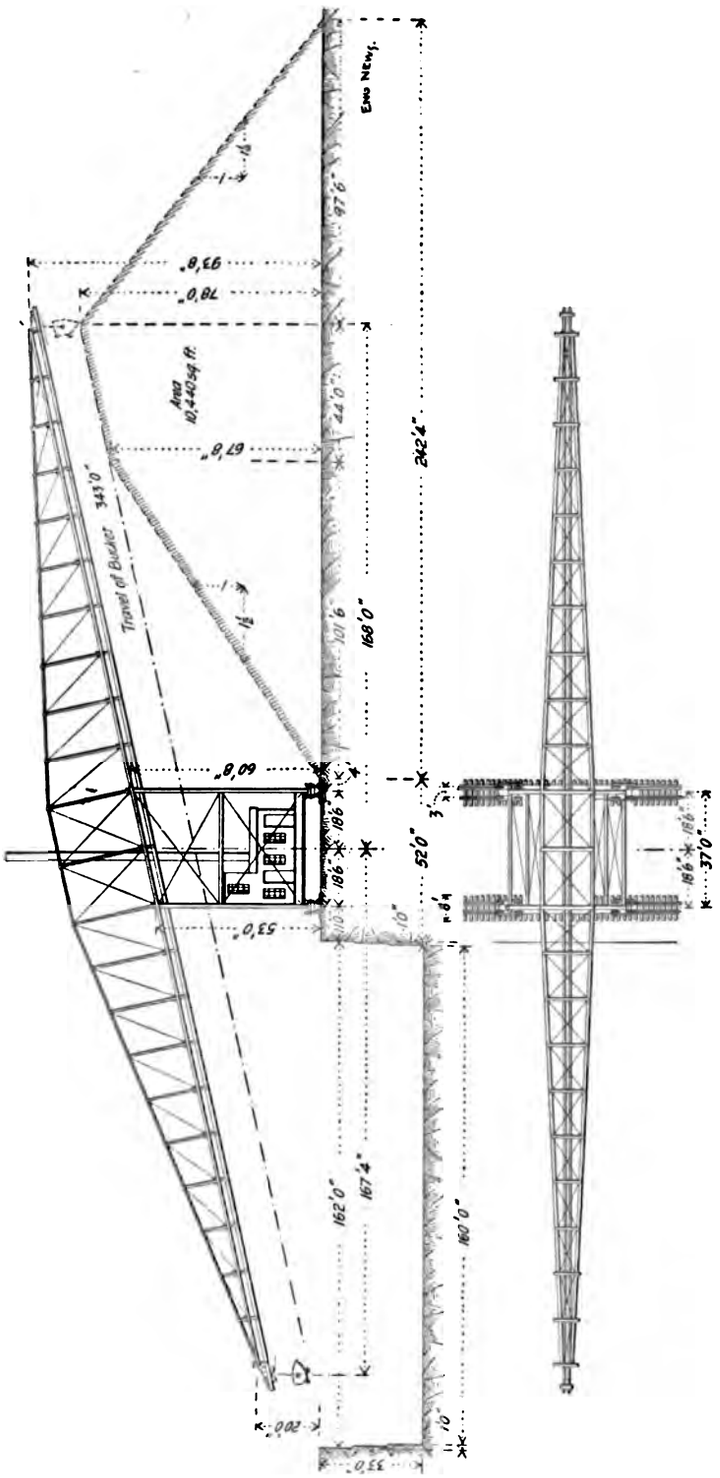


Fig. 75. Elevation and Plan of Brown Cantilever Crane.
THE BROWN HOISTING & CONVEYING MACHINE CO., Cleveland, O., Builders.

Along the line of the lower chords of the trusses is a track on which a carriage or trolley travels, as shown by the elevation, Fig. 75. This carriage is operated by a cable from a 10½ × 12-in. hoisting engine placed on the tower car. The same engine also operates the cable for hoisting the skip, and the machinery for propelling the crane along the canal berm. All the movements of the machinery are controlled by three levers, one of which makes the connections to hoist the bucket, one moves the carriage, and the other actuates the propelling machinery. The travel of the skip is 343 ft., and it can be dumped by an automatic

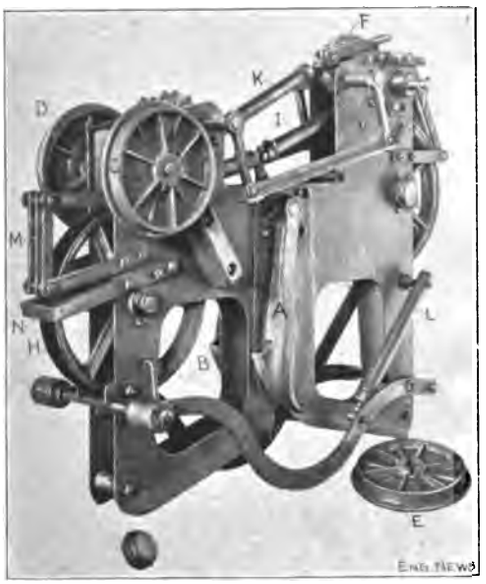


Fig. 77. Carriage for Brown Cantilever Crane.

arrangement at any point in its travel. In moving along the berm the speed can be varied from 150 ft. to 400 ft. per minute. The weight of the entire machine is 150 tons, and its cost about $28,000.

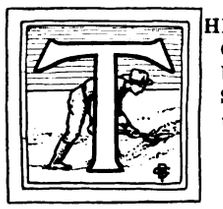
Fig. 77 is a view of the carriage, which is somewhat complicated but unusually handsome piece of mechanism. The exact method of the operation of this carriage in conveying and dumping the skip is not given out, but in a general way it is as follows: The fall block to which the bail of the skip is attached has two hubs, or, more exactly, the axle of the fall block sheave projects on each side. When the fall block is hoisted these hubs strike the pieces A and B on the inclined lower edge and swing them forward, allowing the hubs to pass up into the opening, clearly shown by the illustration. Here the hubs of the fall block are caught and locked, so that when the hoisting rope is slackened the carriage supports the full weight of the fall block and its load. In this condition the carriage is hauled along the track on which it runs on the track wheels C, D, E and F, shown at the top corners of the carriage. It will be noticed that the upper right-hand track wheel has been removed, and is shown detached at the lower right-hand corner of the engraving. When in its progress along the track the carriage reaches the dumping trip, the lever G is actuated in such a manner that the catch locking the bail to the skip is loosened, and the bucket revolves on its trunnions, allowing the load to spill out. Other parts of the carriage which may be explained briefly, but whose operation in detail cannot be given, are as follows: H, hoisting rope sheaves; I, K, L, barrels containing springs to return parts to their normal positions after the bucket is dumped; M, guides for ropes, and N, bumper.

The skip is made of steel plate, and has a trunnion on each side to which the bail is hooked. Of course, only one bail is used, which is fastened to the fall block and hooked and unhooked from the skips as they are loaded and emptied. Each skip has a capacity of 75 cu. ft. water measure, or about 1¾ cu. yds. of rock in place.

The method of operating the cranes is practically the same on all sections, although, of course, the disposition of the labor force and special details differ on different sections. These differences will be described in their proper place, but it may be stated here that in all cases a face extending transversely across the channel is worked by blasting down the rock and loading it by hand into the skips, which are strung along the foot of the face. A skip, as soon as loaded, is hoisted, conveyed to the spoil bank, dumped and returned to its place in the pit, and another taken and returned, this operation going on as continuously as the loading of the skips will permit. Since the crane will handle from 25 to 30 skips per hour, it will be seen that it will have to do more or less waiting for the skips to be loaded, the amount of delay depending upon the character of the rock, the weather, the number and efficiency of the laborers, etc. Such figures of delays as are available will be given in a future article, where the controlling conditions in each particular case are described.

CHAPTER XI.

LOCKPORT DIVISION.



HE Lockport Division of the Chicago Drainage Channel begins at the east end of Section 9, and continues to the end of the channel or the west end of Section 15, embracing about 7 miles of the channel. This is essentially the rock division of the Drainage Channel, there being 6,940,439 cu. yds. of rock excavation and only 747,630 cu. yds. of glacial drift excavation. The amount of retaining wall is also considerably less than on either of the two divisions immediately preceding the Lockport Division. As a consequence, practically all of the plant on the division is designed for excavating and conveying solid rock, the thin layer of glacial drift overlying the rock having been removed by hand-loading into dump cars and carts, with the occasional use of steam shovels where local deposits of earth occurred in the shape of mounds or pockets. The engineering work of the Lockport Division is in charge of Mr. Charles L. Harrison, Division Engineer, Lockport, Ill. We are indebted to Mr. Harrison for much aid in securing the matter from which the articles on Sections 9 to 15, inclusive, have been prepared.

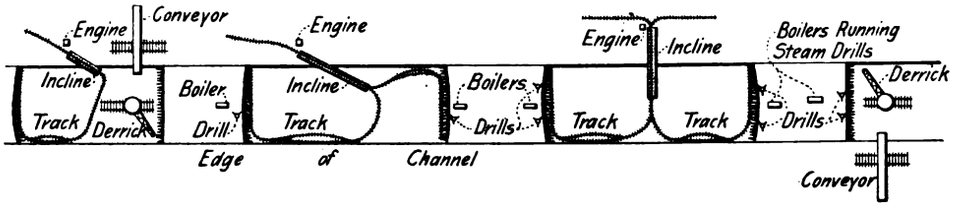


Fig. 78. Plan of Track System Showing Method of Excavation on Section 9.
HALVORSEN, RICHARDS & CO., Chicago, Contractors.

Section 9.

This is the last of the group of sections contracted for originally by Agnew & Co. On Jan. 17, 1894, it was assigned by that firm to Halvorsen, Richards & Co., who have pushed the work ahead vigorously. Like Section 8, this section is essentially a rock section, the revised estimates showing 1,022,310 cu. yds. of solid rock excavation and only 115,450 cu. yds. of glacial drift excavation, 40,741 cu. yds, of which were in the river diversion channel. The prices for excavation are 26 cts. per cu. yd. for glacial drift and 76.9 cts. per cu. yd for solid rock.

Hand labor has been used on Section 9 to a greater extent than on any other section of the canal, by far the larger part of the material excavated having been taken out by dump cars and incline hoists. In 1894 the average daily force worked was 397 men and about 150 cars. The largest force worked during any month was in October, when 586 men, 20 teams, 176 cars and 1.7 conveyors took out 67,800 cu. yds. of rock.

The method of working the incline hoists is pretty clearly shown by Fig. 78, which is a sketch plan of the incline hoists and track system as they stood in July, 1895. Two of the hoists are double hoists; that is, they work two faces each, and the other is a single hoist working one face. The rock is broken down by blasting a row of 26 2-in. holes 2 ft. deep, transversely across the canal and charging them with dynamite. About 1 lb. of explosive is used per cubic yard of rock excavated. Ingersoll-Sergeant drills are used, and are run by steam from portable boilers. Generally two drillers and helpers are worked on each face.

After the rock is blasted it is loaded into ½-cu. yd. cars, which are hauled to the spoil bank in trains of 12 cars for the top lift and in trains of 10 cars for the lower lifts. About 30 men are worked on each face loading cars, and five men sledging large rocks, and one foreman manages the work. Two teams are used in the pit to haul the trains to the foot of the incline when loaded and back to the face when empty. A Lidgerwood hoisting engine, with a ⅝-in. plow steel cable, hauls the trains up the incline itself. On the dump five men and two teams care for the cars hauled up each incline. Two trains are used on each face, so that there is no delay waiting for empty cars. The

economical distance of haul is said to be 1,000 ft.

Through the courtesy of the contractors the following figures of the output per 10-hour shift of all three inclines have been furnished for a period of five months:

Month.	Dble. hoists, work'g 2 faces each. No. 1. Cu. yds.	No. 2. Cu. yds.	No. 3. Cu. yds.	Sgl hoists, working 1 face. No. 3. Cu. yds.
March, 1895	488	516	570	...
April, "	488	484	538	...
May, "	494	442	...	242
June, "	508	495	...	247
July, "	521	518	...	229
Average per hoist	499.8	491	554	239½
" " face	249.9	245.5	277	239½
Av. per man on face.*	6.94	6.82	7.69	6.65

* 36 men—viz., 30 loaders, 5 sledgers and 1 foreman.

These figures are worthy of particular notice, especially those showing the output per man per 10-hour shift, as will be seen by comparing them with the similar figures of cableway output given previously, and also with the outputs of the cantilever cranes, which will be given in future articles. In making these comparisons the comparative costs of the plants should be noted. If this first cost be considered, it will be seen that the incline hoist is one of the most economical methods of ex-

Fig. 79. View of Section 9, Showing Derrick and Conveyor Plant.

McMyler Mfg Co., Cleveland, O., Builders.

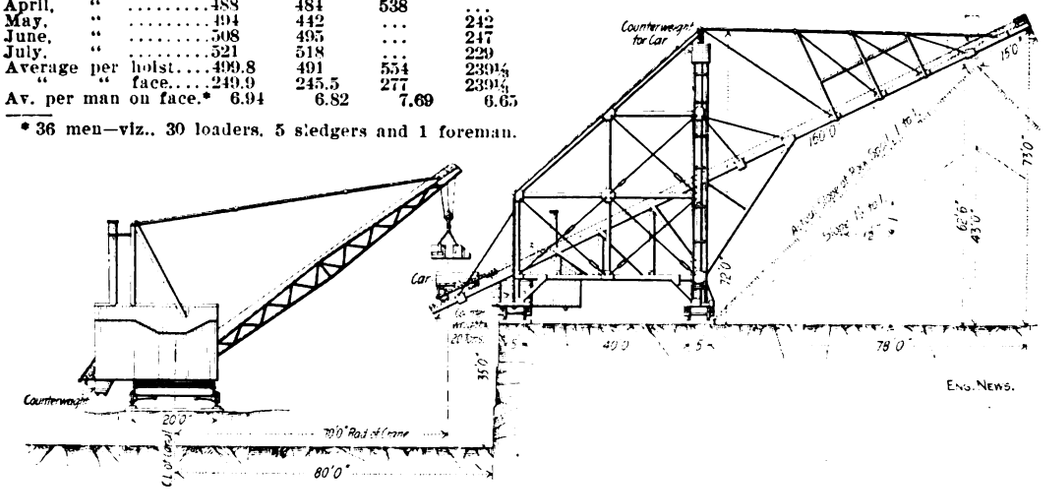


Fig. 80. Elevation of Derrick and Conveyor Showing Construction and Operation.

cavating rock in use on the canal. In fact, the contractors of Section 9 have demonstrated that the entire rock work of the canal could have been excavated by this method at the prices which are being paid without the use of any other machine. Of course, the success of the inclines on Section 9 has been largely due to the careful and systematic management of the work, but this applies to other methods of work as well, and as there will be occasion to show later it is the same important element that has determined the line between success and failure in every part of the work, from the smallest to the largest detail.

This illustration shows the conveyor as originally constructed; since its installation the length of the conveyor has been increased to 170 ft.

The method of operation is as follows: The revolving derrick is placed on a track running longitudinally about the middle of the channel, and the conveyor runs on a track placed on the berm. The derrick skips are strung along a working face extending transversely across the channel and are filled by hand. After being filled the skip is raised by the derrick and its contents emptied into the car running along the conveyor. This car is hauled to the upper end of the conveyor overhanging the

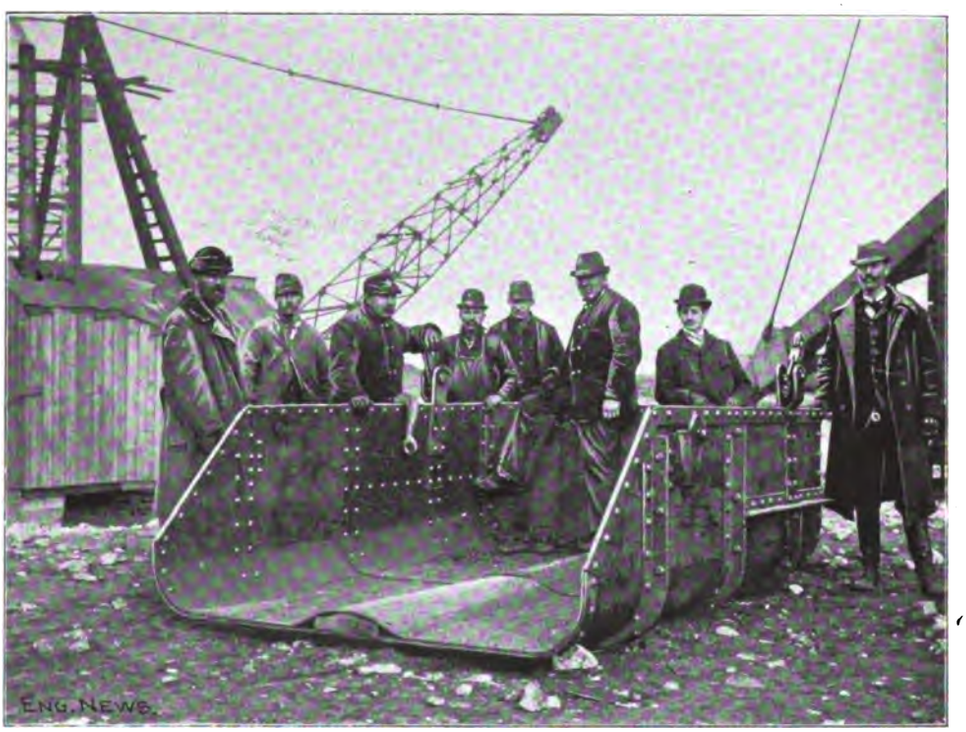


Fig. 81. View of Skip for Revolving Derrick, Section 9.

The drills and channelers used were supplied by the Ingersoll-Sergeant Drill Co., 7 channelers and 15 drills altogether being used. The daily average of the channelers for seven months of 1894 was 94 sq. ft. for each machine. This channeling was done on the first, second and third lifts, and all cuts were 12 ft. deep. For six months of 1894 the daily average of the drills was 82 lin. ft. each.

In addition to the incline hoists, two plants, each consisting of a derrick and a conveyor, have been used for taking out rock and have shown very satisfactory results. Fig. 79 is a view of the channel showing these two plants at work, and Fig. 80 shows in more detail the construction of the revolving derrick and cantilever conveyor forming a plant.

spoil bank, where the load is dumped. About eight skips and 50 men are worked on each face.

The capacity of the car is 8½ cu. yds. water measure and 4.3 cu. yds. of rock in place, and the corresponding capacities of the skips are 7 cu. yds. and 3.6 cu. yds. One skip load makes about a carload, so that in operation the car is dumped every time the skip is emptied into it. Some idea of the size and construction of one of the derrick skips can be obtained from Fig. 81. The derrick engine is of 50 HP., and the conveyor has a 75-HP. engine. The safe load for each is 10 tons. The total weight of the derrick, including counterweight is 85 tons and of the conveyor 60 tons. The machines cost about $15,000 and $10,000, respectively, or

$25,000 for one plant. As stated before, two of these plants are worked on the section.

The exact cost of operation is hard to ascertain. An engineer, fireman and dumper are required for each machine, besides which there are a general superintendent, 12 trackmen, 1 machinist, 1 mechanic and a night watchman divided between the two plants. The wages of these men per shift for each plant are about $18.37. Approximately two tons of coal are burned each shift, costing, say, $2.25 per ton, and about $1 for water, oil and waste used. Allowing $5 per shift for repairs, the total cost for one plant per shift is $28.37.

One of the chief advantages of this combination of derrick and conveyor is found in its ability to handle large rocks. These are, of course, chained into the conveyor car by the derrick without using the skip. The dimensions of some of the large stones measured by the writer in the spoil bank show pretty clearly the ability of the machines to handle large blocks. The following are examples of the dimensions of stone measured: 5½ × 5 × 2 ft. or 55 cu. ft.; 7 × 4 × 2¾ ft., 77 cu. ft., and 7 × 6 × 2½ ft., 105 cu. ft. The average output of these two plants during 1894 was 330 cu. yds. for each plant per day worked. The average daily output for each plant for December, 1894, was 449 cu. yds.

Section 10.

As on Section 9, the excavation on this section was almost entirely solid rock, there being only a thin layer of glacial drift covering the rock surface. Exactly stated, there were 62,083 cu. yds. of glacial drift, and 1,199,546 cu. yds. of solid rock excavation on the section, and this material was taken out at 25 cts. and 80 cts. per cu. yd.,

Fig. 82. View of Section 10 Showing Method of Excavation by Dump Cars and Cable Incline.

E. D. SMITH & Co., Romeoville, Ill., Contractors.

respectively. The contractors are E. D. Smith & Co., who were awarded the work July 13, 1892. From its beginning the work has been signalized by good management and freedom from trouble. On Sept. 3 the last rock was removed from this section. The event was marked by appropriate ceremonies, and a tablet recording the date was fixed to the rock wall near Lemont.

In loosening the rock the same methods were employed on this section as on those preceding; that is, channeling, drilling, and blasting. Sullivan channelers and Rand drills were used, and the air for the drills was furnished by two 18 × 30 in. duplex Rand compressors. These compressors were

Fig. 83. General View of Sections 12 and 11 Showing Character of Rock Channel and Progress of Work.
MASON, HOGE & CO., Romeoville, Ill., Contractors.

located near the center of the section and pumped into two 15-ft. × 45-in. receivers, from which a 6-in. pipe ran in opposite directions up and down the section. Steam was supplied by four 16-ft. × 66-in. boilers. The plant was rated at 28 drills capacity. As a usual thing the holes were put about 12 ft. apart, and about the same distance back from the face of a single row across the channel.

After the rock is broken it is transferred to the spoil bank by one of two methods. For the upper lift, and also to some extent for the lower lifts, tram-cars hauled up cable inclines have been used. Fig. 82 shows one of these hoists on the top lift with the cars arranged along the working face for loading. The tracks are arranged in a loop, as the illustration clearly indicates, so that the empty cars take the outside track in descending, and pass around the curve ready to take the place of the loaded cars without delay. Twelve cars are used, and they are hauled away, two at a time, as fast as loaded. The force worked consisted of 36 loaders, 1 foreman, 1 engineman, 1 switchman, 1 cableman and 5 men on the spoil bank. The average output per loader per day was from 7 to 8½ cu. yds.

The second method of conveying the rock out of the pit is by the well-known Brown cantilever crane, manufactured by the Brown Hoisting & Conveying Machine Co., of Cleveland, O., especially built for this work.

This machine was fully described in Chapter X., and attention can be turned to its work on Section 10 at once. In submitting figures of output of the cranes, the contractors for Section 10 wrote as follows:

The following figures are the averages per 10-hour shift for one cantilever crane worked on Section 10 for the month of March, 1895. The crane worked one 10-hour shift per day. We have had some months better than this and some not so good, but this is a good average for machines working on the lower lift.

The figures given were as follows:

Number of shifts in month	25
Total cubic yards excavated	13,014
Number of skips worked on each face	9
Number of laborers worked on each face	48
Number foremen worked on each face	2
Wages of laborers, per hour, cts.	15
Wages of foreman, per hour, cts.	30
Wages of crane engineers, per month	$75
Wages of crane firemen, per month	60
Tons of coal burned, per shift	2 to 2½
Cost of coal, per ton on siding	$1.75
Average skip-load, cu. yds. in place	1.6

The average output per 10-hour shift, according to these figures, was 520.4 cu. yds., or 10.4 cu. yds. per man worked on the face per 10-hour shift.

According to the records of the Division Engineer, Mr. C. L. Harrison, the outputs of the three cranes worked for six months, February to July, 1895, inclusive, were as follows.

Month.	No. worked. Cranes.	Shifts.	Total excavated, cu. yds.	Cu. yds. excav't'd per shift.
February, 1895	3	50	25,500	510.0
March, "	3	76	32,300	425.0
April, "	3	69	37,400	542.0
May, "	3	78	38,500	493.6
June, "	3	72	35,400	491.6
July, "	3	76	36,800	484.2

Lumping together the work for the entire six months, it is found that three cranes excavated 205,900 cu. yds. of rock in 421 10-hour shifts, or an average of 489 cu. yds. per crane per shift. Assuming that an average of 50 laborers and foremen were worked on each face, the output per man per 10-hour shift for the six months was 9.98 cu. yds. These figures are, of course, far more valuable as a basis for estimating the efficiency of the cranes than those covering only one machine operating for a single month. In a future article still more complete records of cantilever work will be given.

Sections 11, 12 and 13.

The contractors for these three sections of the channel are Mason, Hoge & Co., who were awarded the work on Sections 11 and 12 on July 13, 1892, and for Section 13 on July 27, 1892. For this reason, and because the character of the work and the machinery used are nearly the same on all three sections, they will be described together. Although nearly the last sections to be described, they were among the first to be put under contract, and as the work has been prosecuted diligently by the contractors, they are rapidly approaching completion. A pretty fair idea of the appearance of the work as it stood in the summer of 1895 may be obtained from Fig. 83, which is a view looking east and showing Sections 12 and 11 in the foreground, with Sections 10, 9 and 8 curving around toward the right in the distance. To the right of the main channel is shown a glimpse of the Illinois & Michigan Canal and the tracks of the Chicago, Santa Fe & California R. R., while the main channel can be traced to the horizon by the white line of the spoil banks.

The amount of work on these three sections and the prices paid for each class are as follows:

	Glacial drift.		Solid rock.		Ret'n'g wall.	
Sect'n.	Cu.yds.	P'ce, cts.	Cu.yds.	P'ce cts.	Cu.yds.	Price.
11....	49,788	30¼	1,001,183	79¼	.....	....
12....	41,739	30¼	1,000,500	79¼	10,000	$3.50
13....	35,000	26	1,053,700	74¾	20,000	3.50
Total.	126.527	....	3,054,383	....	30.000	

Of the total 3,180,900 cu. yds. of excavation, practically all but 751,000 cu. yds. will be removed by Brown cantilever cranes exactly similar in construction to those described in Chapter X. These machines have been operated by the manufacturers, the Brown Hoisting & Conveying Machine Co., of Cleveland, O., the contractors paying this firm a certain price per cubic yard for removing the material after it was loaded into the skips.

Before taking up the work of these cranes a few words need to be said regarding the excavation done previous to putting them into operation. Altogether the glacial drift excavation amounted to only 126,527 cu. yds., and was merely the cleaning off of from 1 ft. to 2 ft. of earth overlying the rock. Teams, wheelbarrows and other ordinary methods of work were used and call for no especial mention. On Section 11, there was a considerable levee work done, and the contractors received an additional price for this. Such solid

rock as was removed before the cranes began work was taken out with dump cars and cable inclines, with the usual tracks in the pit and on the spoil bank. Some very good work was done with the incline on Section 12. Two faces were worked, and the output per face per 10-hour shift averaged 322 cu. yds. for nine months worked in 1893.

Turning now to the work of the cantilever cranes, Table IV. shows the force worked, output and wages paid in operating the cranes on each section for the month of October, 1894. In submitting these figures, the Brown Hoisting & Conveying Machine Co. wrote:

Enclosed find the blanks filled out for the month of October, 1894. This month was selected as one in which there were but very few interruptions, the contractors' men working nearly every day. We have assumed 27 ten-hour shifts for each machine, all of the cantilevers, excepting No. 7, working the greater portion of each day. The delays were on account of waiting for material, laborers, etc., and include the time lost by men not being on the work on account of rain and for other reasons. Cantilever No. 7 lost three full days while we were replacing a driving disk. For wages paid to laborers and foremen you will have to

TABLE IV.—Showing Amount of Rock Handled, Number of Employees and Wages of Employees for Cantilever Cranes Worked on Sections 11, 12 and 13 in October, 1894.

	Section		
Cu. yds. exc. per crane per shift....	544.4	488.8	541.8
No. skips worked on face.....	9	9	9
Av. skipload, cu. yds.....	1.72	1.57	1.74
No. laborers and foremen on face..	43	45	46
Cu. yds. exc. per man per shift....	12.66	10.86	11.77
Pay of laborers, cts. per hour.....	15	15	15
Pay of foremen per shift.....	$3.00	$3.00	$3.00
Pay of crane engr. and fireman....	$2.25	$2.25	$2.25
Pay of oiler for crane.....	$1.75	$1.75	$1.75
Pay of towerman or operator.....	$2.75	$2.75	$2.75
Tons of coal burned per shift.....	1.63	1.54	1.56
Cost of coal per ton.....	$1.73	$1.73	$1.73
Total hours' delay, all cranes.....	126	189	170
	11.	12.	13.
ing Machine Co. wrote:			
No. 10-hour shifts in month.....	27	27	27

ask the contractors, as they are employed by them. ($3.00 per day for foremen; 15 cts. per hour for laborers.—Ed.) We put down the wages paid to the three men employed to operate the cantilevers. For coal we had to take the average for the month and then divide it by 27, the number of working days in the month, and assumed that as the average for the shift. The remainder of the figures will explain themselves.

The figures in Table IV. are self-explanatory with the exception, possibly, of those referring to delays. In operating a machine of this kind there are necessarily two causes of delay: (1) Accidents and small repairs to the crane itself, and (2) delays waiting for the skips to be loaded, blasts to be made and other waits on the excavating force. Dividing the figures of total delay of all cranes into these two classes of delay, for each machine the following results are obtained:

	Hours' delay in month due to crane.	Hours' delay in month due to contractors.
Crane 1, section 13.....	13	34
" 2, " 13.....	0.5	48
" 3, " 13..	9	65.5
" 4, " 12.....	6	72
" 5, " 12.....	4	49.5
" 6, " 12.....	15.5	42
" 7, " 11.....	37	27
" 8, " 11.....	8.5	58.5
Total delay, eight cranes.	93.5	291.5

These figures were furnished by the Brown Hoisting & Conveying Machine Co., and are for the month of October, 1894, only.

Table V. has been compiled from the records of Division Engineer Mr. Charles L. Harrison, and shows the number of cranes worked on each section, the number of 10-hour shifts worked and the average output of each crane for 12 months.

The foregoing figures have related almost exclusively to the work of the cantilever crane conveyors, and are in all cases, except where otherwise noted, based on a 10-hour working day and on the number of days actually worked. As a matter of fact, 9, 10 and 11-hour shifts were worked, and both day and night shifts, although practically all of the work was done in the daytime. During February, March, April, May, September, October and November, 10-hour shifts were worked; in June and July and August, 11-hour shifts, and during December and January, 9-hour shifts.

The method of excavation in its general features is alike on all three sections, the rock being blasted down in a face extending transversely across the channel and loaded by hand. Both Ingersoll-Sergeant and Rand drills are used, the number of each being as follows:

	Sec. 11.	Sec. 12.	Sec. 13.
Ingersoll-Sergeant	15	11	7
Rand	2	—	10

On Sections 11 and 13 air is supplied by 18 × 30-in. duplex Rand compressors, and on Section 12 two Ingersoll-Sergeant straight line air compressors are used.

The methods of drilling differ somewhat, not only on different sections, but sometimes on the same section. The holes are usually 12 ft. deep and drilled in a single row across the channel and about 8 ft. back from the face. The number of holes in a row varies, but generally it is either 16, 18 or 22. From two to three drills are used to put in these holes, and one drill is worked on the large blocks.

Aside from the rock excavation already noted, the principal work on Sections 11, 12 and 13 has been the construction of a retaining wall on Sections 12 and 13. When work was begun it was not expected that much retaining wall would be needed, but as the excavation proceeded numerous pockets and seams of clay were found, which, when they broke into the sides of the channel, had to be filled with masonry. One of these pockets is shown in the right-hand wall about the middle foreground of Fig. 81. Often the pocket did not come to the surface within the limits of excavation, but appeared like the heading of a tunnel in the channel wall with a layer of solid rock above, as well as below, and on the sides. The pockets were sometimes globular in shape, and showed the marks of attrition, indicating that they were pot-holes worn by the action of water and boulders, and sometimes they appeared to be crevices or cracks in the bedrock. All were filled with clay which seemed to contain finely-ground limestone, and the mixture cut as smoothly and firmly as a cheese, and when burned gave a hard brick of

a grayish white color, which took a very satisfactory polish. This property was taken advantage of by the laborers, who, in their idle moments, carved out various uncouth and heathenish beasts and baked them for ornaments. These clay pockets caused considerable trouble to the channeling machines, as will be noted further on, and added materially to the cost of the sections.

Cantilever Crane Work.—The conditions of the work on Sections 11, 12 and 13, together with the very complete records of output given in Table V. enable a very satisfactory determination of the capacity of the cantilever crane on the canal work. The eight machines used on these three sections were all operated by the manufacturers after a nearly uniform system, and, it is fair to presume, in such a manner as to develop their best qualities. The figures of output cover an entire year's work for each machine comprising both winter and summer months.

Summarizing the figures of output, we find the average for each crane to be as follows:

	Sec.11. Cu.yds.	Sec.12. Cu.yds.	Sec.13. Cu.yds.
Av. output per 10 hrs. per crane	494.6	489.1	472.2
Av. output per man per 10 hrs...	11.5	10.86	10.26

Lumping together the work of all eight machines 1,107,300 cu. yds. of rock were taken out in 12 months, or 485.3 cu. yds. per 10-hour shift worked, or 10.87 cu. yds. per shift per man worked on the face. There were 306 working days in the year, or 2,448 working days for the eight machines, making the output per 10-hour working day 451.9 cu. yds.

The figures of delay cover but one month, but they may for various reasons be assumed to represent quite fairly the average delay per 10-hour shift for the year. Summarizing these figures, we get the following:

	Crane No. 1.	2.	3.	4.	5.	6.	7	8.
Hrs.' delay per ten hours	1.74	1.79	2.76	2.88	1.98	2.13	2.37	2.29

A delay of 2¼ hours per 10-hours may thus be expected for each crane, but of this delay only 0.43 hour is due to the machine itself, the remaining time being delays waiting for the skips to be loaded, for blasts, and for other purposes for which the crane is not responsible. It should be remembered that these delays are figured per working day, and not per day worked.

The cost of operating each crane per 10-hour shift is not easy to get at with exactness, but from the figures obtainable it seems to be about as follows:

Pay of engineer and fireman	$2.25
Pay of oiler	1.75
Pay of operator	2.75
Cost of coal	2.75
Laying track	.50
Cost of water, oil and waste	.25
Total	$10.25

The cost of repairs, a very important item, is not known, nor is it possible to know just what proportion of the expense of watchman's service and superintendence goes to each machine. The above are the items of cost of operation which vary the least with the varying conditions of the work and varying output, and may be roughly assumed to be constant whether the crane removes 300 cu. yds. or 600 cu. yds. per day.

The cantilever crane, like the cableway, is a conveying machine, and its output is greater or less up to a certain limit, according as the rapidity of excavating the rock and loading the skips approaches the capacity of the conveyors. One of the cranes has taken out 892½ cu. yds. in 10 hours, and 4,845 cu. yds. in a week. These, of course, are exceptional records, but they serve to show to what a great extent the capacity of the machine depends upon the rapidity of work in the pit. The hardness of the rock, character of the weather, efficiency of labor and superintendence and a dozen other variables determine the rapidity of work in the pit. The value of the figures of output given above lies in the fact that they involve all these variables, or, in other words, are records of actual outputs of rock excavated, extending over a considerable period of time and covering a number of machines.

TABLE V.—Showing Number of Brown Cantilever Cranes Worked, Number of 10-Hour Shifts Worked, and Output per Shift of 12 Months, February, 1894, to January, 1895, Inclusive, on Sections 11, 12 and 13.

	Section 11. No. cranes worked.	No. shifts worked.	Cu. yds. per shift.	Section 12. No. cranes worked.	No. shifts worked.	Cu. yds. per shift.	Section 13. No. cranes worked.	No. shifts worked.	Cu. yds. per shift.
Feb., 1894	2	44.4	306.4	2	44.5	359 6	4	91.3	346.1
Mar., "	2	39.7	372.8	2	50.5	455.4	4	95	443.2
April, "	2	41.2	526.7	2	41.5	506.0	4	90.5	540.3
May, "	2	49.5	391.9	2	43.1	391.4	4	85	489.4
June, "	2	55.8	491.0	2	50.3	447.3	4	109.4	488.1
July, "	2	53.8	553.9	2	51.7	566.7	4	109 6	514.6
Aug., "	2	81 8	440.1	2	51.1	514.7	4	113.7	468.8
Sept., "	2	48.8	627 1	2	47.3	539.1	4	96.3	396.7
Oct., "	2	49.6	592.7	3	76.9	514 9	3	78.6	558.5
Nov., "	2	45.6	541.7	3	69.8	485.7	3	61.7	420.4
Dec., "	2	38.6	707.2	4	74.1	530.4	2	38	605.3
Jan., 1895	2	41.4	490.4	4	83.7	494.6	2	33.9	471.7
Twelve months		599 2	494.6		684.5	489.1		1.005	472.2

Section 14.

This section has been in the hands of two contractors since work was begun. The first contractor was the McCormick Construction Co., which was awarded the work July 13, 1892, at the prices of 20 cts. per cu. yd. for glacial drift, 73 cts. per cu. yd. for solid rock and $2 per cu. yd. for retaining wall. After some delay the contractors got into shape to do work, but owing to an insufficient plant, poor management, lack of

money and various other causes, it was not pushed with the energy it should have been. The affairs of the company went from bad to worse, until finally, in November, 1893, they were placed in the hands of a receiver and all work was stopped. Upon notice of work being stopped the Board of Trustees sent a notice of action for forfeiture to the contractors, but before actual forfeiture was declared the receiver assigned the contract to Smith & Eastman, with the consent of the Trustees.

Up to the time when work was stopped 45,300 cu. yds. of glacial drift and 118,600 cu. yds. of solid rock had been excavated, and the terms of the assignment provided that the assignee was to continue the work in every respect as called for in the original contract and in conformity with certain additional stipulations which the progress of the work had shown to be necessary. These stipulations called for the construction of an embankment on either side of the channel. The embankment on the west side of the channel was required to run the whole length of Section 14 and 4,000 ft. west on Section 15, and to be 30 ft. wide on top and 8 ft. above Chicago datum. On the east side of the channel the embankment was to be of the same dimensions and to extend 4,000 ft. into Section 15, but to run only part of the length of Section 14. The material for constructing the embankments was taken from the main channel in part and partly borrowed, and an additional price of 16 cts. per cu. yd. was allowed for the east embankment and for 4,000 ft. of the west embankment.

With this modified arrangement the amounts of materials and prices stand as follows: 213,045 cu. yds. glacial drift at 36 cts. per cu. yd., 166,210 cu. yds. of glacial drift at 20 cts. per cu. yd., 1,023,500 cu. yds. of solid rock at 73 cts. per cu. yd. and 22,000 cu. yds. of retaining wall at $3.25 (estimated) per cu. yd.

The method of doing the glacial drift excavation and building the embankments calls for no especial mention. Steam shovels were used to excavate the material and load it into tramcars, which were hauled by locomotives to the dumping ground. Teams and small dump cars hauled up cable inclines were also used. At the busiest time, three locomotives, one cable incline, about 60 large and 15 small dump cars, two steam shovels and a dozen teams were used. The steam shovels were of the Giant type, manufactured by the Vulcan Iron Works Co., of Toledo, O., and the dump cars were manufactured by the Sheffield Velocipede Car Co., of Three Rivers, Mich. These cars proved very satisfactory both in their working and their durability. The capacity of the large cars is 5 cu. yds., or 20,000 lbs. The inside measurement of the box is 8 ft. × 9 ft. × 1 ft. 10 ins., and the height of the top of box above the rail is 6 ft. 11 ins., and the length over all is 13 ft. The wheels are 24 ins. in diameter, with 4 ins. tread, and weigh 318 lbs. The wheel base is 6 ft. and the gage is 4 ft. 8½ ins. The axles are of steel, 3½ ins. at center, 4 ins. wheel fit and 3¾ × 7-in. journals. The oil boxes are of cast iron, with lead-lined brass bearing and axle and stops. The drawbar head is of cast iron, with heavy double-coil draw springs and continuous drawbar. The truck frame of the car is oak, as also is the box frame, all being thoroughly bolted and strengthened by a strong truss at each end. The bottom, sides and ends of the box are of oak, 1¾ ins. thick, and the bottom of the box is lined with 3-16-in. steel plate. The box is riveted on three sets of strap hinges, and will tip at an angle of 40°. The door is also hinged on heavy cast iron hinges, with central bolt, and is securely locked shut by means of levers dropping into place by gravity and automatically secured in place by means of a locking lever at the opposite side of the car. This same lever also locks the box in position for loading. The ironwork is all covered with one coat of asphaltum, and all the exposed portions of the woodwork are painted with two coats of best mineral paint.

While the glacial drift excavation was going on, the contractors were busily at work installing a plant suitable for excavating the large amount of rock. At the beginning it was decided to adopt high-power derricks for removing the rock from the pit, the idea being that these machines would not only be efficient for the work in hand, but they they could be used afterwards for quarry work, and therefore stand a good chance of being easily sold. For such a character of excavation as the work on the channel demanded, the derricks were largely experimental, and it was found that many features of construction suitable to a quarry derrick must be modified in order to make them suitable to the canal work. These modifications were not of great difficulty, but they took time, and meanwhile the work fell behind in progress. Indeed, it was not until late in the autumn of 1894 that all the machines were completed in satisfactory working order and the work of removing rock begun at such a rate as to assure the completion of the excavation in a reasonable time. Since that time the contractors have shown some wonderful records of excavation, removing as much as 167,900 cu. yds. of solid rock in place in two months.

Altogether six derricks are used, four of which are self-contained, double-boom, traveling derricks mounted on turntables, and two are double-boom fixed derricks, which work together on opposite sides of the channel. The traveling derricks were designed by Dion Geraldine, of Chicago, Ill., and the fixed derricks by the American Hoist & Derrick Co., of St. Paul, Minn.

Fig. 84 is a view of one of the double-boom traveling derricks. Of the three other traveling derricks, one is the twin of the derrick illustrated, and the other two differ in having one boom of wood and in other details, but are like each other. The derrick illustrated is, however, the latest improved design, and a description of its general construction will answer exactly for its twin, and in a general way for the others. Fig. 85 shows the two wooden boom derricks, of which the one

on the left hand was the first one constructed, and was afterward changed so that the center tower rose to a point instead of being truncated. The reason for this change is obvious, and now both are exactly alike, or as shown by the right-hand machine in Fig. 85.

Returning to Fig. 84, it will be seen that the derrick is erected on a platform or frame, which is carried on rollers that travel on temporary timbers or skids laid on the berm. On this frame is a turntable, which carries the main floor or platform of the derrick, to which are attached the superstructure and machinery. The rack of this turntable is 28 ft. in diameter, and by means of it vertical pinions, operated by two 8 × 8-in. vertical engines, revolve the derrick on its axis.

The superstructure of the derrick consists of a pyramidal center tower of timber framework 113 ft. high from apex to track, and of two trussed steel booms 164 ft. and 155 ft. long, respectively. Two fall blocks are hung from each boom, the lines going to the hoisting engines on the platform, and there are also the proper sheaves and connections for raising and lowering the booms. The Sketch, Fig. 86, together with Fig. 84, will enable a clear understanding of the arrangement of the fall block ropes and other lines. Take first the fall block ropes. From the engine drums the rope for fall block No. 1 runs up the boom to a, b, c and d, and for fall block No. 2 to e, f, g and h, as shown in Sketch 1. The line for raising and lowering the boom runs up the tower, Sketch 2, to A and thence to B, C, D and E, Sketches 1 and 2. The arrangement of the fall block lines for the opposite boom is just the same as described above, but as a sheave for raising this boom is attached between the two sets of boom sheaves for the two fall blocks, as well as at the

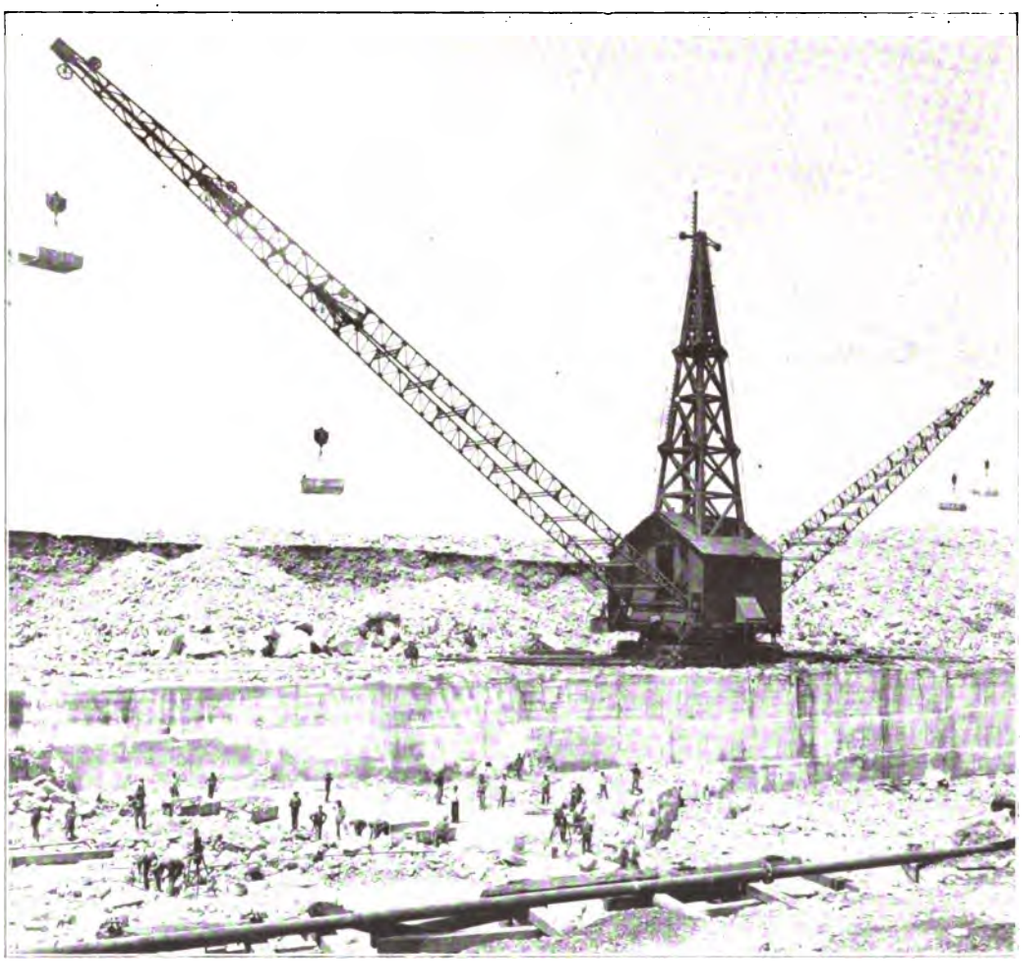


Fig. 84. Double Steel Boom Derrick for Removing Rock, Section 14.

SMITH & EASTMAN, Lockport, Ill., Contractors.

tip of the boom, a somewhat different arrangement of the boom lines is necessitated. A glance at the near boom of Fig. 84 will show the difference of arrangement.

built by the Gates Iron Works, of Chicago, Ill., and has done especially satisfactory work. As will be seen, the engine has four winding drums, two adjacent to each boom, on each pair of which

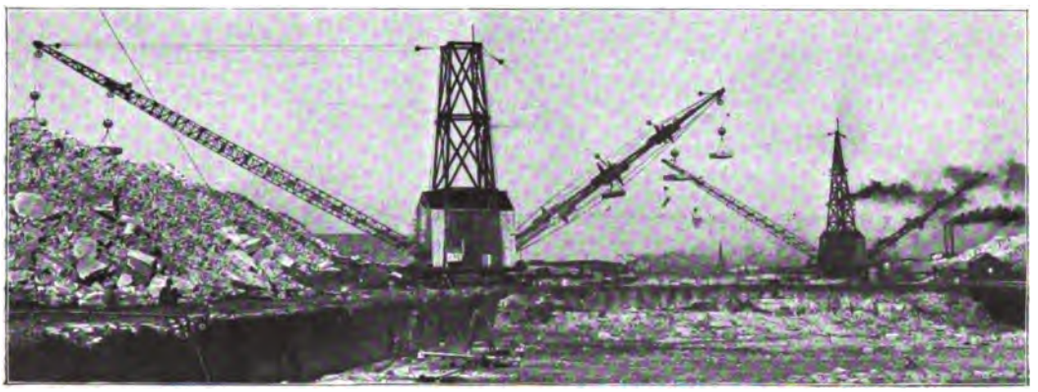
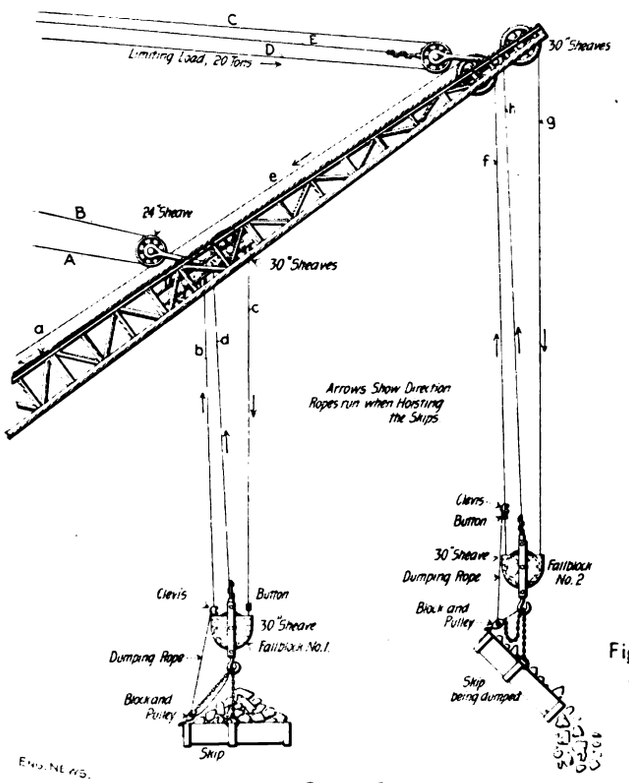
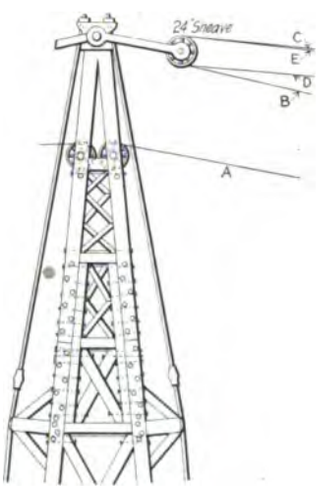


Fig. 85. View of Section 14, Showing Derricks With One Steel and One Wooden Boom.



Sketch 2,
Showing Operation of Dumping Device



Sketch 1,
Showing Top of Central Tower.

Fig. 86. Sketches Showing Connection and Operation of Fall Block Ropes, Dumping Devices, Etc., Double Boom Derricks.

The four fall blocks are operated by a four-drum hoisting engine placed on the derrick floor. Fig. 87 is a side elevation of the engine used in the derrick shown in Fig. 84. This machine was

the ropes from the two skips of each respective boom are wound, the object being to lift both skips on one boom and lower both skips from the end of the other boom simultaneously while

the derrick is being revolved. When the proper point for dumping has been reached by the loaded skips, they are automatically dumped, and the loaded ones are attached to the tackle of the other boom by the workmen in the cut.

The engine rests upon a base, which supports it sufficiently above the floor to allow clearance for the spur wheels on the two lower drum shafts. The engine beds are connected to and mounted upon this base, and in turn support the main side frames in which are journaled the two upper drum shafts, and also support the operating platform, upon which are arranged all the levers for the proper manipulation of the entire derrick. Upon the upper and lower drums of each end the lifting ropes from the skips on that side are wound.

The engines are 12 × 16 ins., and make 200 revolutions per minute, and are coupled to the crank shaft at an angle of 90°. Upon the crank shaft are mounted the spur pinions that engage with the main spur wheels on the drum shafts of the front drums—that is, the drum near the crank end of the engine. The rear drums, upper and lower, are driven by means of an intermediate shaft, having pinions engaging with their spur wheels, and also with the pinions on the crank shaft, for the purpose of imparting to the drum the proper direction of rotation. The drum shafts all run continuously, and the power is applied to the drum through the means of the well-known Mundy friction arrangement. At the end of each drum, opposite the spur wheel, is provided an auxiliary dumping drum for the purpose of automatically dumping the load at any given point in the lift, by means of which the dumping point may be instantly varied at the will of the operator. The Gates Iron Works have patented this device. This device is not used on the canal work, as will be described later.

The engines used for the other three derricks were made by the Webster, Camp & Lane Machine Co., Akron, O., and one of them is shown by Fig. 88. They have 11 × 15-in. cylinders and 60-in. drums, and are mounted on a continuous bed-plate. The operating levers, including those for operating the throttle and reverse motion, are grouped on an elevated platform, as shown. The illustration shows this to be in every respect an unusually compact and handsome machine.

The manner of operating all four derricks is the same. While one boom overhangs the channel, the other overhangs the spoil bank, and each boom carries two fall blocks, to which are attached two skips; thus two loaded skips are being attached in the pit, just as the two opposite skips are being dumped. As soon as two skips are attached in the pit, the engineman begins to raise them and swing them around out of the pit and over the spoil bank, and at the same time to lower the skips on the opposite boom, which the turning motion is bringing over the pit. The raising of the loaded skips continues until the button of the hoisting rope actuates the dumping rope, Fig. 85, and empties the skips. Hoisting is then stopped, while the opposite skips, which have reached the pit, are unhooked and loaded skips hooked in their place. This process of hoisting, turning and lowering of the skips is repeated as continuously as the rapidity of loading them will permit.

A face about 12 ft. high and extending diagonally across the channel is worked, and the number of loaders worked on each face, the cost of operating the derrick working that face, the wages paid, cost of coal, etc., are shown in the following table:

No. laborers worked on face	50 to 60
No. foremen worked on face	1
Wages, laborers, per hour	15 cts.
Wages, foremen, per month	$75.00
No. skips worked on face*	12 to 14
Av. skip load, cu. yds.	2
Wages, derrick engineman, per shift	$2.50
Wages, derrick fireman, per shift	1.75
Wages, derrick trackmen (two), per shift	$3.00
Tons coal burned per shift	2
Cost coal per ton on ground	$2.00
Cost oil, water, waste, watchman and superintendence per shift	5.00

* Two of these skips are constantly attached to boom.

With this labor force loading the skips and operating the derricks, the output of each derrick for five months of 1895 was as shown in Table VI. These figures have been calculated from the records of the Division Engineer, Mr. C. L. Harrison, and show the output of rock in place per day worked. Lumping together the work of all four derricks for five months, it was found that the average output of each per 10-hour shift was 300.6 cu. yds., or assuming an average of 56 men to have worked regularly on each face, the output per man per 10-hour shift was 5.36 cu. yds.

Fig. 89 is a view of the two fixed derricks in position for work. As will be seen, they stand on opposite sides of the channel, and are guyed together and to anchors in the ground. As originally constructed, both derricks had double booms, but afterward one boom was removed from the right-hand derrick, making it a single-boom derrick. These derricks were built by the American Hoist & Derrick Co., of St. Paul, Minn.

Both derricks are operated in exactly the same manner, so that the description of the operating machinery for one of them will answer for the other. For this purpose the double-boom derrick, with metal mast and booms, will be taken. Fig. 90 shows this machine very clearly. The mast is 130 ft. high and the booms 120 ft. long, and all are trussed as shown. This superstructure is mounted on a timber platform, which can be skidded along the canal bank on rollers. The power machinery is placed in a house separate from the derrick, but also mounted on rollers. Briefly described, it consists of a four-drum double engine, two drums of which operate the fall block ropes and two the ropes for hoisting and lowering the booms. The same engine operates a winch, from which a rope passes around a disk, or "bull wheel," fastened to the bottom of the mast. By winding the rope on the winch the derrick is revolved on its vertical axis. The method of operating the derrick in removing and dumping the

rock is nearly the same as used with the traveling derricks previously described.

The two derricks are ordinary high-power quarry derricks, and the faults which have developed in their operation on the canal have been due to this fact. In quarry work a rapid hoisting and revolving motion is not often desired, owing to the slowness of excavation; but on the canal work the rapid removal of rock is the prime essential. Consequently the sluggish movements of the derricks have been a drawback to their success on the Drainage Channel, although they would doubtless give excellent service in quarry work. Other things have also contributed to the small output of the fixed derricks (see Table VI.), among which is poorer work of excavation, the contractors preferring to concentrate their best efforts on the work of the traveling derricks.

TABLE VI.- Showing for Five Months the Number of Ten-Hour Shifts Worked and the Output per Shift for Each of the Six Derricks Worked on Section 14.

Month.	Traveling derricks. No. 1. No. shifts worked.	No. 1. Cu. yds. per shift.	No. 2. No. shifts worked.	No. 2. Cu. yds. per shift.	No. 3. No. shifts worked	No. 3. Cu. yds. per shift.	No. 4. No. shifts worked.	No. 4. Cu. yds. per shift	Fixed Der'ks. Nos. 5 and 6. No. shifts worked.	Fixed Der'ks. Nos. 5 and 6. Cu. yds. per shift.
March, 1895	48.2	211.6	30.5	124.6	43.0	286.0	47.8	271.9	71.1	137.8
April, "	50.1	297.4	46.7	235.5	48.6	345.7	47.1	371.5	90.1	150.9
May, "	43.0	344.2	53.1	184.5	50.3	441.3	51.9	405.6	64.3	147.7
June, "	48.1	261.9	33.8	165.7	22.3	322.8	42.9	342.6	77.7	145.4
July, "	49.5	327.3	26.1	256.7	47.4	438.8	48.0	333.3	53.7	210.4
Five months	238.9	288.4	190.2	189.4	211.6	366.9	237.7	344.9	356.9	158.5

Turning now to the general features of the work, it has already been stated that a 12-ft.

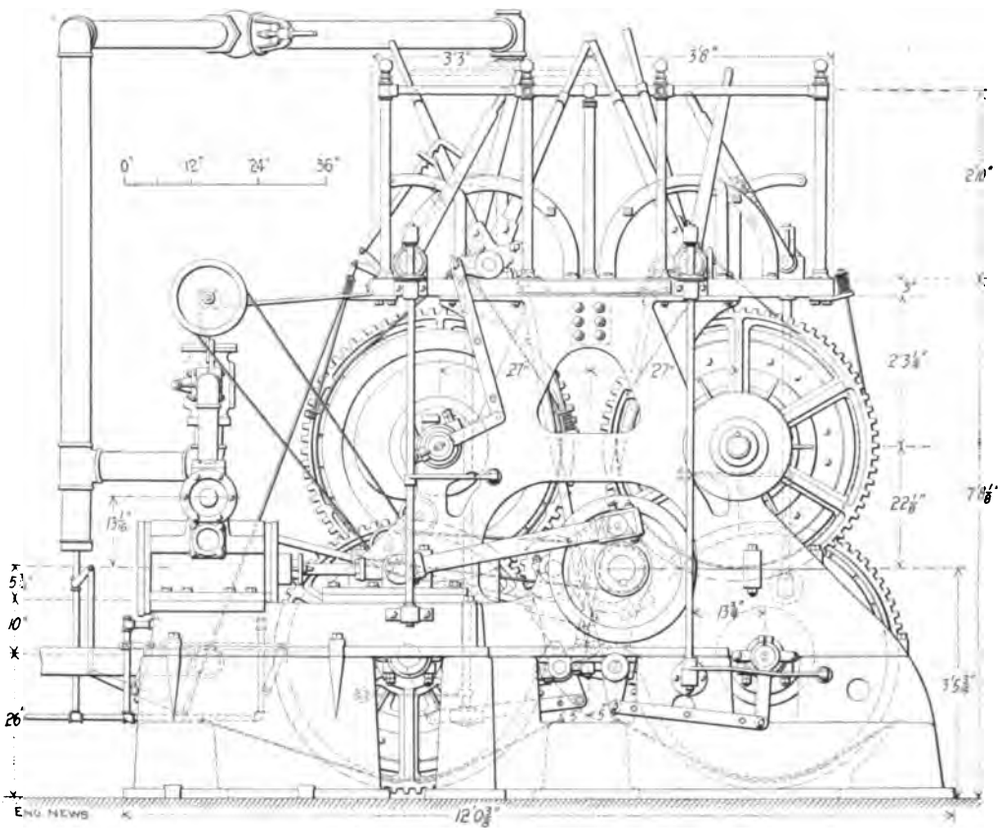


Fig. 87. Hoisting Engine for Double Boom Derrick Shown in Fig. 84.

GATES IRON WORKS, Chicago, Builders.

face extending diagonally across the channel is worked. The length of this face is about 225 ft., and generally from 30 to 33 12-ft. holes, 9 ft. back from the face, are drilled, and the entire face

broken down at once blast. Both Ingersoll-Sergeant and Rand drills are used, and four drills are worked on each face. The explosive used is dynamite, 40% glycerine, and it requires about 1 lb. per cu. yd. of rock excavated. Air is supplied by a 20 × 36 × 20¼-in. Corliss duplex Ingersoll-Sergeant compressor, which pumps into 5 × 10-ft. receivers. The compressed-air pipe is 10 ins. in diameter at the receivers and decreases to 4 ins. at the ends. This pipe is shown in the foreground of Fig. 84 with one of the joints for contraction and expansion at the extreme right. The channeling is done by seven Ingersoll-Sergeant channelers.

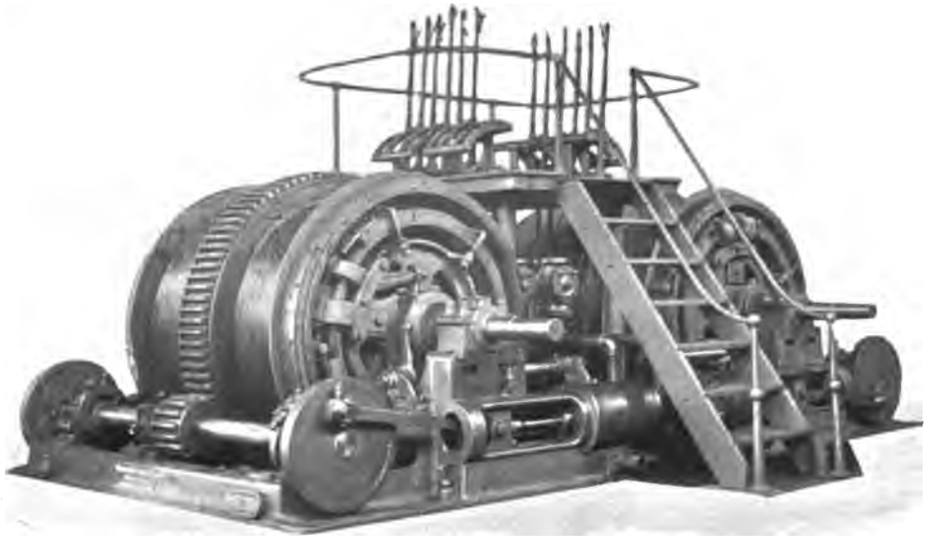


Fig. 88. Hoisting Engine for Double Boom Traveling Derrick Shown in Fig. 85.

WEBSTER, CAMP & LANE MACHINE CO., AKRON, O., Builders.

Section 15.

The work on Section 15 involved the construction of regulating works to control the outflow of the main channel into the Desplaines River below Lockport; and to provide for these works considerable modification was made in the previous uniform cross-sections of the channel. Fig. 91 shows a part plan of Section 15. It will be seen that the channel, beginning with the regular width of 160 ft. at the north end of the section, begins to widen out about 1,000 ft. from the south end until it reaches a width of 503 ft. at the extreme end. Forming the lower portion of the west wall of this windage basin are the bear-trap dam and

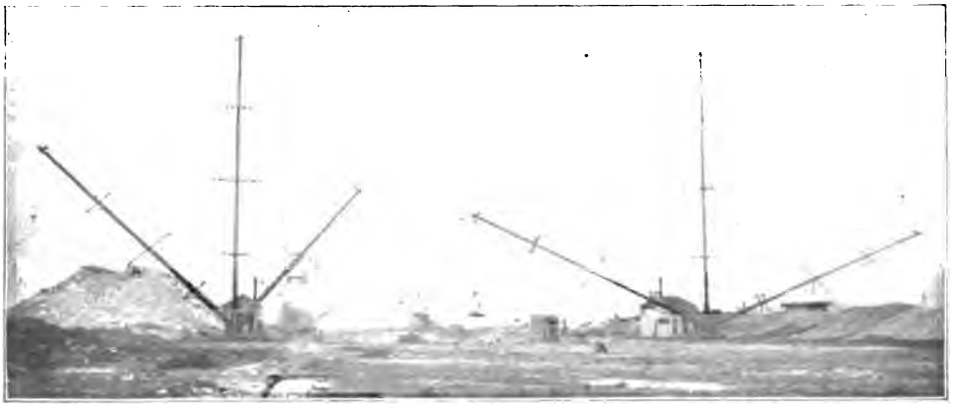


Fig. 89. Double Boom Fixed Derricks in Working Position, Section 14.

AMERICAN HOIST & DERRICK CO., St. Paul, Minn., Builders.

gates constituting the regulating works, and from these will run the tailrace which will deliver the discharge to the Desplaines River. The general layout of the work being plain from these drawings, attention may now be turned to the work in detail.

Excavation.

The contract for excavating 36,000 cu. yds. of glacial drift and 639,700 cu. yds. of solid rock, and building 37,400 cu. yds. of retaining wall on Section 15, was let Aug. 29, 1894, to Wright, Meysenberg,

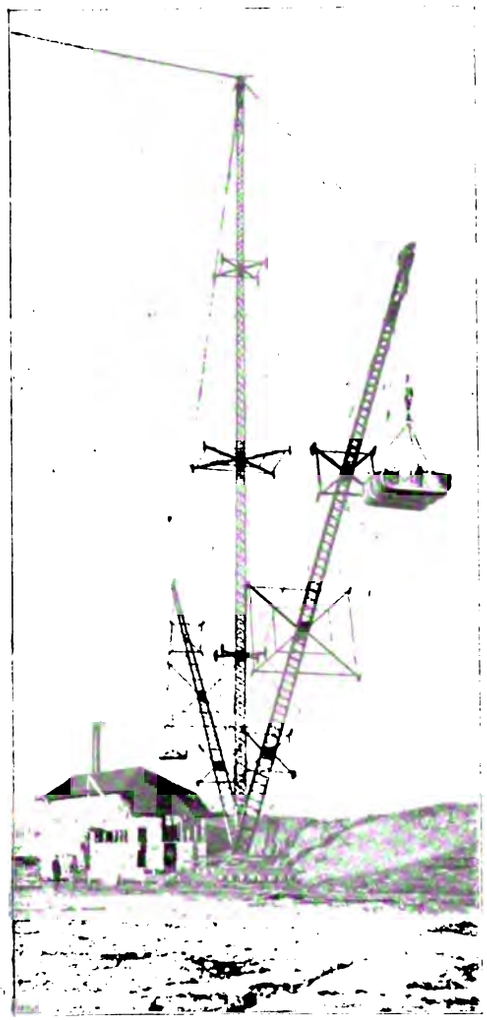


Fig. 90. All Steel Fixed Derrick Showing Manner o Carrying Skip.

Sinclair & Carry, of Chicago, Ill., the prices for the different work being, respectively, 19 cts. per cu. yd., 59 cts. per cu. yd. and $2.35 per cu. yd. This contract, it will be noted, included no part of the regulating works. In devising a plan for doing the excavation, the contractors had to take into consideration: (1) That no spoil could be deposited at a level above 8 ft. above datum; (2) that no material could be wasted on the south side of the channel, and (3) that no material could be wasted opposite any point on the lower 1,000 ft. of the channel. On a portion of the work a considerable length of haul was necessary, while the depth of excavation was small compared with that of the preceding sections, being from 18 ft. to 22 ft.

After carefully considering different methods, the contractors decided (1) to load all blasted rock with steam shovels; (2) to carry the spoil by locomotives and cars on the lower and south end of the section where the width was great, and (3) to convey the spoil by means of cable inclines on the north end of the section where the width was only 160 ft. The chief point of novelty in this is the use of steam shovels in handling the rock.

The rock is first channeled by Ingersoll-Sergeant channelers, and then blasted down and loaded by the steam shovels. Ingersoll-Sergeant drills are used, and the holes put down about 20 ft., sometimes in linear rows and sometimes staggered with each other, or in zigzag rows. The explosive most used is forcite, but Aetna and Atlas powder are also employed. At the south end of the section, where locomotives are used to haul the spoil, the loading is done by two Bucyrus special shovels. These shovels load into 5-cu.-yd. cars, which are

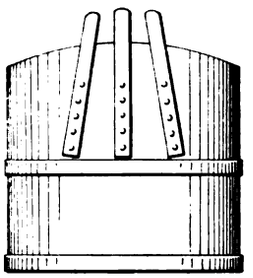


Fig. 93. Sketch showing Arrangement of Dipper Teeth for Handling Rock.

Fig. 92. View of Section 15, showing Steam Shovel Handling Blasted Rock.

hauled in trains of 10 cars. Two locomotives are used. Fig. 92 shows one of the steam shovels loading rock. These shovels differ from the ordi-

nary shovel for handling earth only in the construction of the dipper. This is 2¼ cu. yds. in capacity and rather shallow, with three teeth, the middle tooth being straight and the two side teeth inclined toward the middle tooth, as is clearly shown in Fig. 93.

The following figures, taken from the records of Division Engineer Charles L. Harrison, show the output of the shovels for four months, and may be considered as a fair general average of what they are doing on the canal:

Month.	No. 10-hour shifts worked.	Total cu. yds. exc.	Cu. yds. exc. per shift.
May, 1895	108.9	20,000	266
June, "	99.0	28,850	291
July, "	96.0	29,000	302
Aug., "	102.4	31,800	310

The maximum output of one shovel in 10 hours has been 600 cu. yds. These figures show the output of rock in place; when blasted, the volume increases to about 1.8 times its original bulk.

Where the cable inclines are used, the method of channeling, drilling and blasting the rock is practically the same as that just described, but the loading is done by hand. Two inclines are used: one with 24-in. gage track and ¾-cu. yd. cars, and the other with 36-in. gage track and 1½-cu. yd. cars. The cars are hauled up the incline one at a time by a 10 × 12-in. double-cylinder Lidgerwood hoisting engine, and teams handle them in the pit and on the spoil bank. Generally 35 men are worked in the pit and two men on the dump for each incline. The wages paid are $1.50 per day for ordinary laborers and $3 per day for foremen. A 16¼ × 16 × 36-in. Ingersoll-Sergeant compressor furnishes the air for running the drills.

CHAPTER XII.

CHANNELING MACHINES.

HE problem of channeling the sides of the rock sections of drainage channel offered difficulties never before met with by channeling machines. This class of machinery had heretofore been used exclusively on sound stone of the higher grades, such as marbles, oolitic, limestone and sandstones. Any quarry that was not sound was soon abandoned, and all the unsound layers of rock were almost invariably removed by blasting before the channeler was set to work. On the canal varied very considerably from place to place, and often changed in a few hundred feet. In places it was hard, compact and flinty, with bands of chert, and in other places it was soft, shaken and filled with mud pockets. In a number of places the rock would be apparently sound on the surface, and a few feet down a pocket filled with clay would develop. In other places the whole rock wall would prove to be shaken up and full of seams, often running parallel with the channel cut, so that when the bit reached a depth of 6 or 8 ft. the whole side of the cut would cave in. Frequently cuts had to be abandoned for this reason before the depth of 12 ft. was reached, and it was

TABLE VI. Showing Work of Five Ingersoll-Sergeant Channelers on Section 8, and Cost of Operating the Same Per Day During the Month of May, 1894.

	Channeler No. 1.		Channeler No. 2.		Channeler No. 3.		Channeler No. 4.		Channeler No. 5.	
Date.	Sq. ft.	Cost.	Sq. ft.	Cost.	Sq. ft.	Cost.	Sq. ft.	Cost.	Sq. ft.	Cost.
1	135	$11.25	50	$10.00	113	$10.00	122	$11.25	150	$ 8.75
2	133	11.25	118	8.75	75	8.75	137	8.75	175	8.75
3	149	6.85	75	6.85	75	6.85	111	6.85	149	6.85
4	180	8.75	75	8.75	112	8.75	146	8.50	175	8.75
5	113	8.75	125	6.25	50	6.25	52	8.75	140	6.25
6	Sunday	.87	Sunday	.87	Sunday	.87	Sunday	.87	Sunday	.87
7	170	8.75	119	6.25	75	5.10	120	11.25	100	8.75
8	150	11.25	112	6.25	50	8.75	135	5.00	140	6.25
9	200	8.75	100	8.75	50	11.25	50	2.50	...	7.10
10	150	8.13	112	2.70	70	4.65	...	5.00	100	7.66
11	150	8.75	125	6.50	90	10.65	...	6.25	175	8.75
12	220	8.75	50	8.25	112	11.25	...	6.25	140	11.25
13	Sunday	.87	Sunday	.87	Sunday	.87	Sunday	.87	Sunday	.87
14	125	8.75	75	8.87	40	6.25	40	6.25	160	8.75
15	200	8.75	100	6.25	60	8.75	155	8.75	20	2.50
16	150	11.25	87	6.25	50	8.75	134	11.25	180	8.75
17	100	5.62	87	8.75	50	8.75	155	5.62	140	8.75
18	75	8.75	150	5.62	50	5.37	190	8.75	65	5.62
19	...	4.95	100	8.87	40	6.25	105	8.75	175	11.25
20	Sunday	3.57	Sunday	1.50	Sunday	.87	Sunday	.87	Sunday	.87
21	175	8.75	100	9.75	...	8.75	145	9.25	150	8.75
22	100	13.75	112	9.75	...	8.75	190	13.75	160	6.25
23	180	6.25	60	6.25	87	6.25	180	6.25	125	6.25
24	200	11.25	...	9.50	140	11.25	175	11.25	175	11.25
25	175	8.75	100	8.75	85	11.25	221	11.25	150	8.75
26	200	8.75	150	8.75	140	8.75	153	8.75	65	8.75
27	Sunday	.87	Sunday	.87	Sunday	.87	Sunday	.87	Sunday	.87
28	170	8.75	50	11.25	157	8.75	200	11.25	122	7.50
29	125	8.75	112	6.25	105	11.25	141	11.25	160	5.50
30	150	8.75	112	11.25	120	8.75	143	8.75	...	.....
31	145	8.75	100	11.25	210	6.25	125	10.00	...	5.50
Total.	4,020	$247.98	2,556	$220.77	2,206	$229.85	3,325	$234.95	3,291	$206.71

Total cost of blacksmithing, oil, hauling and machinist in charge of five channelers for 31 days, $205.65.

entirely different conditions prevailed. The object in using the channeling machines was to secure as solid, unshaken and sound a wall as possible, and the more shaky the rock, the more important it was to keep the effect of the powder from the walls, and the channeler cut did this as nothing else could.

The limestone on the rock sections of this work not at all unusual on some sections to find the machine blocked up on timbers, working over a cut 2 or 3 ft. wide at the surface where the broken rock had fallen in and been removed by hand.

On the second and third cuts a new element of trouble came from the shaking of the rock by the explosions. When by chance the channel cut

bottomed at or near a natural bed, or plane of stratification, the effects of the blast would hardly be felt on the rock below; but when the cut happened to come halfway through a bed, so that in removing the face the holes were drilled a foot or more below the bottom of the channel, the explosion would shatter the rock badly within the channeled line, so that when the next cut was put down the rock would be solid on the outside and shaken on the other, causing the "cuts" to run and become so crooked that the machine could not force the steel through them.

Again, on certain sections where there was a great deal of water, and when the contractor failed to take the necessary pains to draw it away from the walls, it would cover the surface where the channeling was being done, making it impossible for the runner to see what he was doing. This was especially bad in loose places on the second and third cuts. The rapidity with which the faces of the excavation advanced made it very troublesome to provide water for the channeling machines in cold weather, particularly on those sections where there was not earth enough to protect the water pipes from frost.

The following figures will give an idea of the variation in results owing to different conditions. The two machines selected were Sullivan No. 101 on Section 12 and No. 111 on Section 13. The cutting is taken from daily reports. That done in June, 1893, was on the top lift under favorable weather conditions, the short hours being accounted for by time lost in a labor disturbance.

The January, 1894, reports were taken under the most unfavorable conditions, third lift cutting, cold weather with the usual accessories of frozen water pipes, ice and snow; and in the case of machine No. 111 there are included five night shifts, which in winter means additional trouble. The time figured is that for which the men were paid, which includes all time lost for repairs and delays.

	Channeler 101.		Channeler 111.	
	June, 1893.	Jan., 1894.	June, 1893.	Jan., 1894.
No. hours worked ..	205	222	209	209
Sq. ft. channeled....	2,783	1,401	3,076	1,683
Av. sq. ft. per hour..	18.4	6.31	14.24	5.60
Max. sq. ft. per day..	300[1]	126[2]	357[2]	96[3]
Min. sq. ft. per day..	90[1]	18[3]	63[2]	12[3]

[1] 10-hour day; [2] 11-hour day; [3] 9-hour day.

The labor expenses of running the channelers on Sections 12 and 13 were about as follows:

Wages of runner per day	$2.75
Wages of foreman per day	1.75
Wages of helper per day	1.50
Blacksmiths and teams to haul drills	.68
Superintendence, including foreman and machinist	1.33
Cost of coal delivered to machine	2.50
Total	$10.51

The above figures as to blacksmiths and superintendence vary according as the contractor has more or less work for his regular force to do. They are based on employing men for the channelers alone. No figures of cost of repairs, steel, etc., are given.

Fig. 55 (p. 60) is a view of one of the Sullivan channelers, built by the Sullivan Machinery Co., of Chicago, Ill. This particular channeler is at work on Section 3, but the others are like it in all respects. Altogether 53 Sullivan channelers were used on the canal work.

Fig. 73 (p. 72) is a view of the channeler manufactured by the Ingersoll-Sergeant Drill Co., of New York, N. Y., 33 of which have been used on the canal. Briefly described, this machine is a direct-acting vertical channeler, which runs on a 4 ft. 9⅝ ins. gage track out to out of rails. The cutter, or bit, is fastened by a clamp to the piston rod and acts in the line of the piston stroke, just as a rock drill or steam hammer acts. The feed is controlled by a screw. The engine and all its attachments are mounted on a frame, as clearly shown by the illustration, and it takes its steam from a vertical boiler. An independent engine moves the machine along the track. The method of operating is obvious; as the machine moves back and forth along the track the bit cuts a gradually deepening slot or channel.

Through the courtesy of the Ingersoll-Sergeant Drill Co., records have been secured of the work of their channelers on Section 8 described in a previous chapter. These figures are records of work on the top-lift. On the lower lifts the capacity is from one-half to two-thirds what it is on the top lift. The records cover the work of five channelers for the month of May, 1894, and were submitted to the engineers of the Sanitary District for confirmation before they were published. Table VI. shows the daily record of square feet channeled and the cost of operation of each of the five machines

TABLE VII.—Showing Work Done by Ingersoll-Sergeant Channeler No. 1 on Section 8, and the Cost of Operating the Same per Day for the Month of May, 1894.

Date.	Sq. ft.	Runner.	Helper.	Fireman.	Coal.	Total.
1	135	$3.00	$1.50	$1.75	$5.00	$11.25
2	133	3.00	1.50	1.75	5.00	11.25
3	149	2.10	1.05	1.20	2.50	6.85
4	180	3.00	1.50	1.75	2.50	8.75
5	113	3.00	1.50	1.75	2.50	8.75
6	Sunday	....	....	.87	....	.87
7	170	3.00	1.50	1.75	2.50	8.75
8	150	3.00	1.50	1.75	5.00	11.25
9	200	3.00	1.50	1.75	2.50	8.75
10	150	2.70	1.35	1.58	2.50	8.13
11	150	3.00	1.50	1.75	2.50	8.75
12	220	3.00	1.50	1.75	2.50	8.75
13	Sunday	....	....	.87	....	.87
14	125	3.00	1.50	1.75	2.50	8.75
15	200	3.00	1.50	1.75	2.50	8.75
16	150	3.00	1.50	1.75	5.00	11.25
17	100	1.50	.75	.87	2.50	5.62
18	75	3.00	1.50	1.75	2.50	8.75
19	...	3.00	.75	1.20	....	4.95
20	Sunday	1.80	.90	.87	....	3.57
21	175	3.00	1.50	1.75	2.50	8.75
22	100	3.00	1.50	1.75	7.50	13.75
23	180	3.00	1.50	1.75	....	6.25
24	200	3.00	1.50	1.75	5.00	11.25
25	175	3.00	1.50	1.75	2.50	8.75
26	200	3.00	1.50	1.75	2.50	8.75
27	Sunday	....	....	.87	....	.87
28	170	3.00	1.50	1.75	2.50	8.75
29	125	3.00	1.50	1.75	2.50	8.75
30	150	3.00	1.50	1.75	2.50	8.75
31	145	3.00	1.50	1.75	2.50	8.75
Total.	4,020	$80.10	$39.30	$48.58	$80.00	$247.98

Cost for blacksmithing, oiling, hauling and machinist in charge, $43.13.

worked, except that the cost of repairs is not given. Separate figures, however, give the total cost of blacksmithing, oil, hauling, and machinist's services as $205.65. Adding this to the other totals of cost and dividing by the proper quantities give the cost of channeling as 2.8 cts. per cu. yd. of excavation 160 ft. wide, or as 8 1-5 cts. per sq. ft. channeled. The average cut by each machine for 27 working days of the month was 2,279 sq. ft., and the average per day for each machine was 121 sq. ft.

Table VII. shows the work of one channeler and the cost of operating it in somewhat more detail. The cost of blacksmithing, oil, hauling and machinist's services was $43.13, making the cost per sq. ft. 7¼ cts., and per cu. yd. of excavation 160 ft. wide, 2½ cts. The average amount channeled per day was 148.8 sq. ft.

These figures of the cost of channeling should be understood for just what they are: records of work on the top lift and in a firm rock free from seams and pockets. Moreover they must not be taken as a fair record of channeling work all along the canal, either with these or other mashines. Where the rock is seamy and full of pockets the cost of working the top lift will run probably from 25% to 35% higher, and the cost of working the lower lifts is from one-third to one-half greater than the cost of working the top lift in nearly all cases. If the cost of plant is charged against the work, the figures will, of course, be correspondingly greater.

CHAPTER XIII.

REGULATING WORKS.

HE works for regulating the discharge of the main channel into the tailrace leading to Desplaines River consist of a bear-trap dam and a series of sluice gates, as shown by Fig. 91. This illustration shows the general arrangement of the works so clearly that no further general description is needed, and attention may be turned to the details of construction.

Sluice Gate Construction.—Altogether there will be 15 sluice gates, resembling in a general way the well-known Stony gate. These gates will work up and down between masonry piers, and altogether furnish 15 clear openings 30 ft. wide for the flow of water. In the beginning, however, only seven of these openings will be used, and therefore only seven gates will be constructed, but all of the piers will be built at once. At each end of the series of gates there is a suitable masonry abutment, and a roadway coming down the canal bank will be carried over the gates by a series of spans extending from pier to pier.

Fig. 94 shows the design and construction of the masonry piers in detail. Each consists of what, for want of better terms, may be called a body and a tower, and is founded on a concrete footing on solid rock. The body is constructed of dimension-stone facing, backed with Portland cement concrete, and the specifications require that each course of facing shall be laid complete and the backing brought up to its top level before the next course is laid. The same method of construction is required for the towers, which are to have a hard-burned, sewer-brick facing and a natural cement concrete backing. Capstones cover the top of the tower and also the exposed top surfaces of the body. Between the piers are floors of granite block paving laid in Portland cement concrete, and the necessary bearing sills for the gates. Details of the bridge between piers, the fixed shaft supports at the tops of the towers, the snubbing posts and other minor constructions are shown by the illustration.

Fig. 95 shows details of the counterweight and the metal attached to the piers. This comprises bearing sills, gate guides and supports and bearings for the shafts and gearing, by means of which the gates are raised and lowered. In another article full details of the operating machinery will be given, but here the description will be confined to the metal attached to the piers. The bearing sill is of oak, fastened to the foundation with 12 1½-in. steel holding-down bolts, and capped with a bearing rail on which the bottom edge of the gate rests. The hydraulic jack pedestals shown at the bottom are for the purpose of getting a lift on the gate in case the usual lifting mechanism is not powerful enough to raise them, owing to wedging, freezing or similar accidents. The jacks will be used in case of emergency only. The relative location of the so-called side and end elevations of the gate guides is made clear by a study of Fig. 94 in connection with the plan of Fig. 95. These guides are constructed of mild steel and cast iron. All joints between the ironwork and the masonry are compactly filled with Portland cement mortar. It will be noted that a set of leveling screws are provided for adjusting and leveling the guides in construction. The construction of the counterweight boxes is sufficiently explained by the drawings. It will be seen that the weight of the counterbalance is made adjustable by the use of cast iron weights of small size.

The gates are constructed of mild steel, as shown by the elevations and sections in Fig. 96. The drawings are in such detail that no further description is necessary, except perhaps to state that at each end of the gate there will be an anti-friction device inserted in the jaw of the steel casting. The construction of this anti-friction device will be fully described in another article.

The specifications for material to be used in the masonry and metalwork just described are in brief as follows:

Masonry.—The best Portland and natural cements shall be used. The development of tensile strength for Portland cement shall be 400 lbs. per sq. in., after having set seven days, and for natural cement 100 lbs. per sq. in. after having set seven days. All lumpy, dirty or damaged cement shall be rejected; also damaged and short-weight packages. All sand is to be clean, sharp and free from loam or pebbles.

Portland cement mortar shall consist of one part, by volume of the specified Portland cement to two parts of

the specified sand. Natural cement mortar shall consist of one part by volume of the specified natural cement to one part of the specified sand.

The Portland cement concrete shall consist of two parts, by volume, of broken stone to one part, by volume, of the specified Portland cement mortar. The stone and mortar shall be thoroughly incorporated, so as to make a homogeneous mass. In the foundations the concrete shall be laid in courses not exceeding 4 ins. in thickness. The natural cement concrete shall consist of two parts, by volume, of broken stone to one part, by volume, of the specified natural cement mortar.

Metalwork.—No specific process of manufacture will be demanded, provided the material fulfils the requirements of these specifications. The tensile strength, limit of elasticity and ductility, shall be determined from a standard test piece of as near ½ sq. in. sectional area as possible. The elongation shall be measured on an original length of 8 ins. Iron of all grades shall have an elastic limit of not less than 26,000 lbs. per sq. in.

Material.	Ult. strength, lbs. per sq. in.	Elong. in 8 ins., %.	Red. area at fract., %.
Iron:			
High-test or tension	50,000	18	..
Angle and shape iron.....	48,000	15	..
Plates 8 to 24 ins.....	48,000	15	..
" 24 " 36 "	46,000	10	..
" over 36 "	.....	8	..
Rivet iron	50,000	18	..
Pin iron	50,000	15	..
Steel:			
Mild steel	60,000	25	45
Rivet "	60,000	25	50
Pin "	60,000	20	40

Specimens taken from bars of a larger cross-section than 4½ sq. ins. will be allowed a reduction of 500 lbs. for each additional square inch of section, down to a minimum of 48,000 lbs., and have an elongation of 15% in 8 ins. All iron for tension members must bend cold through 90° to a curve whose diameter is not over twice the thickness of the piece without cracking. At least one sample in three must bend through 180° to this curve without cracking. When nicked on one side and bent by a blow from a sledge the fracture must be mostly fibrous.

Specimens from angle and other shaped iron must bend cold through 90° to a curve whose diameter is not over twice the thickness of the piece without cracking. Samples of plate iron shall stand bending cold through 90° to a curve whose diameter is not over three times its thickness without cracking. When nicked and bent cold, the fracture must be mostly fibrous. Full-size pieces of flat, round or square iron not over 4½ ins. in sectional area shall have an ultimate strength of 50,000 lbs. per sq. in., and stretch 12½% in the body of the bar. Bars of a larger sectional area than 4½ sq. ins. will be allowed a reduction of 1,000 lbs. per sq. in. down to a minimum of 46,000 lbs. per sq. in. and stretch 10% in the body of the bar. In all cases the amount for test, cut to size specified above, shall have an ultimate strength of 60,000 lbs. per sq. in.; a deviation of 4,000 more or less than 60,000 will be allowed; minimum elastic limit, one-half the ultimate strength; minimum elongation, 25% in 8 ins.; minimum reduction of area at fracture, 45%.

Before or after heating to a cherry red and quenching in water at 82° F. this steel shall bend 180° to a diameter equal to thickness of the piece tested, without sign of fracture. Any rivet hole for ¾-in. rivet, punched as in ordinary practice (with center not more than 1¼ ins. from edge of piece) shall stand drifting to a diameter 25% greater than the original hole, without cracking, either in the periphery of the hole or in the extreme edges of the piece, whether they be sheared or rolled. Rivets shall bend cold 180°, with sides to close contact without sign of fracture, and shall stand the quenching test at a bright yellow heat.

All steel castings shall have the properties and meet the requirements given in what follows, unless otherwise specified. The amount of phosphorus contained shall not exceed 0.1%; the ultimate strength shall not be less than 60,000 lbs. per sq. in.; minimum elastic limit, 25,000 lbs.; minimum elongation, 15%. All steel castings shall be sound and free from injurious roughness, sponginess, pitting, shrinkage cracks or other cracks, cavities, etc., and shall be thoroughly annealed according to good practice.

When not otherwise specified, all iron castings shall be tough gray iron, sound and free from injurious cold shuts ad blowholes, true to pattern and of workmanlike finish. Sample pieces 1 in. square cast from the same heat of metal in sand molds shall be capable of sustaining on a clear span of 4½ ft. a central load of 500 lbs. when tested in the rough bar.

The specifications for workmanship do not differ materially from those for ordinary first-class work of this character. It is required that all metal before leaving the shop shall be thoroughly cleaned and be given one coat of pure linseed oil: that all surfaces in contact shall receive one heavy coat of approved paint before assembling, and that all finished surfaces shall be coated with white lead and tallow before leaving the shop. After erection all iron and steelwork are required to be thoroughly and evenly painted with two coats of paint of a quality and color approved by the Chief Engineer.

Tower House.—At the south end of the series of sluice gates a tower house for the storage of tools and the shelter of the operators is to be built. This house will be essentially a continuation of the south abutment tower, and will be built of brick and steel, with a steel plate roof designed for a load of 100 lbs per sq. ft. Leading to this roof at the south end of the house there will be a stairway, by which the operators can reach the bridge running along the top of the pier towers. From this bridge the gates will be operated, as is described in the following paragraphs. It may be noted that the illustrations, Fig. 94 to Fig. 99 inclusive, will be found on the accompanying inset sheets.

Machinery for Operating Sluice Gates.—The general arrangement of the sluice gates between the piers and the mechanism for raising and lowering them are shown in Fig. 97. Extending across the top of each pier tower is a fixed steel shaft, 7½ ins. in diameter, keyed to bearings located as shown by the drawings. Turning freely on this shaft at each end, outside of the bearings, is a pocketed chain-wheel, over which traverses a chain, one end of which is fastened to the gate and the other end to the counterweight. The fixed shaft thus carries the weight of the gate and the counterbalance. The chain-wheel revolves on the fixed

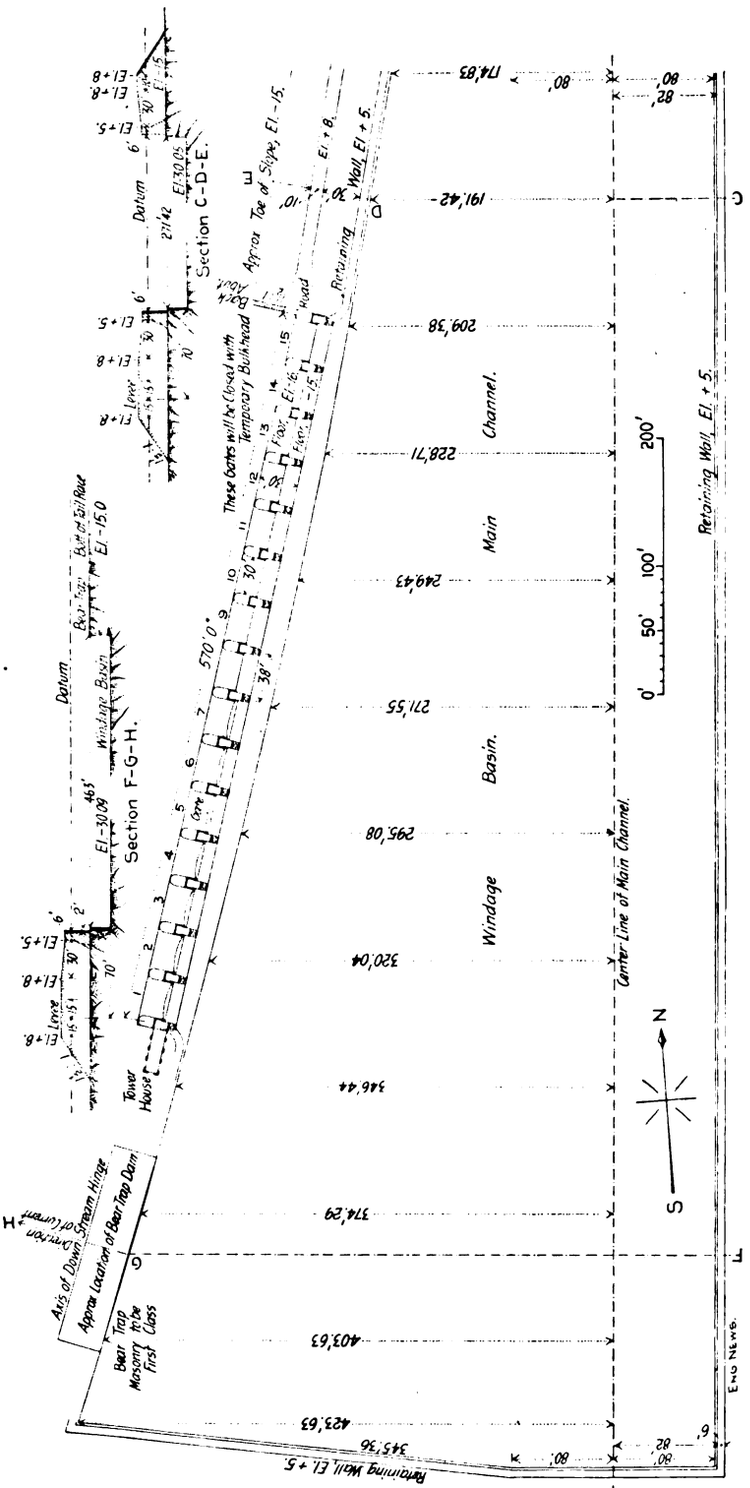


Fig. 91. Plan of South End of Section 15, Showing Windage Basin and Location of Regulating Works.

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shaft, and to its hub is keyed a spur wheel (Fig. 98). It is evident that by causing this spur wheel, and therefore the chain-wheel, to revolve, the gate is raised or lowered, according to the direction of the revolution. This revolution is brought about as follows:

Spanning the space between the piers is a 4-in. steel shaft having a pinion and ratchet wheel at each end. The pinion meshes with the spur wheel on the fixed shaft. By means of a ratchet operated by a hand lever, the ratchet wheel, the 4-in. shaft and the pinion are made to revolve, and consequently the spur and chain wheels. To raise a gate, therefore, a man is placed at the hand lever operating the ratchet at each end of the 4-in. shaft, and by working the levers up and down, like a pump handle, the gates are raised. In raising, the power is applied to the down stroke of the lever, and it will be seen from Fig. 98 that the arrangement of the pawls and ratchet are such that a simple reversal keeps the power on the down stroke in lowering the gates.

Taking the construction up in detail, the first feature of note is the expansion coupling shown in Fig. 97. This coupling is designed to adjust to a change of temperature of 150° F. It will be seen that one shaft end is fixed in the coupling box by a taper key, while the other shaft end is secured from rotating by two parallel keys fixed tight in opposite side of the shaft end, but easily in keyways cut in the box. All journals and shaft bearings, and, in fact, all friction surfaces, are lined with brass or bronze bushings. The spurs, pinions, ratchet and chain wheels are of cast iron, and are so designed that the operating lever will break before the gear teeth will break. Cast iron for gearing is required by the specifications to have an ultimate tensile strength of 30,000 lbs. per sq. in.

The chain is a special pitch crane chain made to fit the pockets of the chain wheel. It is a 1½-in. chain, and, according to specifications, is required to have a breaking strength of 133,000 lbs. and to stand a proof load of 66,500 lbs. without distorting the links.

In a preceding paragraph mention was made of the anti-friction device at the ends of each gate. To each end of the gate there is fastened a cast steel bearing, having a U-section, as shown by Fig. 99. The ends, X, Y, of this U-section bear against the steel-bearing plate Z, fastened to the shoulder of the pier, with a force equal to the pressure of the water against the upper face of the gate, and of course some method of doing away with the friction of this bearing in raising the gate was necessary. To this end the roller train, A, and wedge bar, B, shown by the drawings, were inserted in the jaws of the U-shaped end bearing, as shown in the plan of the end bearing. The wedge bar has a plain face bearing against the rollers of the roller train and a notched, or pocketed, face bearing against a correspondingly-notched, or pocketed, tongue, C, fastened to the U-shaped bearing casting. Turning to the enlarged drawing of part of the wedge bar and roller train, it will be seen that the wedge bar is first inserted so that the wedge surfaces, or notches, on the bar, B, and tongue, C, mesh with each other. There is then a little more than enough space left to insert the roller train, A. Referring still to Fig. 99, it will be seen that if the wedge bar is raised in the direction of the arrow, the wedge surfaces, or notches, on the bar and tongue will cause the face adjacent to the roller train to press against the rollers and shove them in turn against the roller bearing, Z. Evidently, if the bar be raised enough, the rollers will be pushed against the bearing hard enough to push the U-shaped steel bearing casting away from the bearing plate. This being done, the gate is raised and lowered on rollers, and the only friction is the journal and rolling friction of the roller train.

Normally the gates will bear against the roller bedplate as just described—i. e., through the medium of the roller train—but when it is desired to take out the anti-friction rollers and wedge, the wedge is simply forced back in a direction opposite that shown by the arrow, taking the pressure from the roller train and transferring it to the edges X Y of the U-shaped bearing casting. By means of a crane traveling along the bridge between the tops of the towers, the roller train first, and then the wedge bar, are withdrawn.

It will be noticed that the wedge surfaces of the wedge bar and wedge tongue are concave and convex, respectively. By this construction any small deflection in the gate is taken up without tendency to distort the bearing. To aid further in this adjustment, the wedge tongue is made of Tobin bronze, whose ductility is such that a distortion or flow of metal will take place in the tongue before damage is done elsewhere. Of course, it will be understood that the gates are not calculated to deflect enough to require any such distortion of the tongue, nor even to require much adjusting of the concave and convex wedge surfaces. The wedge tongue is constructed of mild steel, and both the plane surface bearing on the rollers and the wedge surfaces are accurately milled. The Tobin bronze was required by the specifications to be hot rolled, to have an ultimate tensile strength of 70,000 lbs. per sq. in., a minimum elastic limit one-half the ultimate strength, and a minimum elongation of 15%.

The roller bedplate is 1½ × 20 ins., with a universal milled roller bearing face. All the rollers are made of pin steel, with brass bushings reamed to exact size and turn on concentric steel pins, with a clearance of 1-64 in. to 1-50 in. The cast steel bearing bolted to the edge of the gate is cast in two parts, which are bolted together at the middle line of the gate. Other details of the bearing casting and anti-friction device are pretty clearly shown by the illustrations.

Bear Trap Dam.—Besides the sluice gates for controlling the discharge of water from the main channel, there will be a bear trap dam. The prin-

ciple of this device is so well known that here attention will be confined wholly to the general design and construction of this particular structure. Details of the dam cannot be given at this time, since in calling for bids the engineers of the Sanitary District gave only the general design, leaving all details to be worked out by the bidder in conformity to certain requirements. The general form and dimensions of the dam are shown by the sketch diagram, Fig. 100. It consists of a downstream leaf, A, hinged at a, and an upstream leaf B, hinged to the downstream leaf at b, and both leaves work up and down between two abutments, C and D, 160 ft. apart. The leaves A and B are to be steel or iron girders of sufficient strength to withstand all forces without undue stress. The crest, d e, is raised or lowered, by admitting or excluding the water from under the dam, but no details of this control of the water are available.

practice. The details are required to be such that no leakage of water underneath the dam shall occur.

It will be seen that the principal difficulties in the design are (1) to make the upstream leaf strong against lateral deflection, due to the water pressure; (2) to secure as nearly as possible a uniform frictional resistance—in hinges and rollers—throughout the entire length of the dam, in order to prevent tilting or one end rising faster than the other, and (3) to devise some form of counterweight whose operation will prevent tilting or one end rising faster than the other. These are all problems due to the great length of the dam. The form of construction adopted to secure these requirements has not been determined in detail and cannot be given here. In respect to the construction of the counterweights so as to adjust the differences of fric-

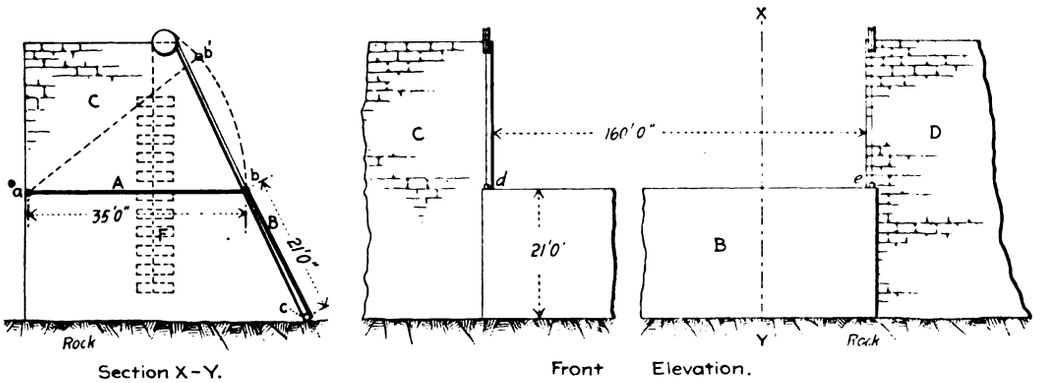


Fig. 100. Diagram Showing Operation of Bear Trap Dam.

To properly balance the weight of the leaves and the available pressure of the water under the dam, the counterweight, F, is provided. The friction roller c runs on a track fastened to the abutment masonry.

The general form and operation of the dam being thus made plain, attention may be turned to the specified requirements for its design. It is required that the maximum weight of the upstream leaf shall not exceed 335,000 lbs. and of the downstream leaf, 520,000 lbs. The friction of the friction roller is limited to an amount not exceeding 10% of the load carried by it, and the coefficient of friction of the downstream hinge (a, Fig. 98) is limited to not over 15%. All stresses are to be within the limits of safety determined by good

tion, the idea of the engineers of the Sanitary District is to have them made up of a series of disks or plates, suspended one above the other with a space of about an inch between them, and, as the dam rises and the counterweight descends, to have these disks come to rest one after the other. By this construction it will be seen that if one end of the dam rises faster than the other, the disks on the counterweight at that end will come to rest faster than those at the other—that is, the pull will be decreased at the fast-rising end and not decreased at the slower-rising end, and the dam will thus tend to come to a level.

In closing this brief description, it may be noted that this will be the largest single length of bear trap in the world.

CHAPTER XIV.

MISCELLANEOUS CONSTRUCTIONS.

P to this time the description of the drainage channel has been confined to the construction of the main and river diversion channels and the works forming integral parts of those channels. There are, however, various supplementary constructions not forming part of the main channel, but yet be essential to its final usefulness, which must yet be constructed. These constructions comprise: (1) Tail-race and channel to carry water through the city of Joliet, Ill.; (2) supply channel to furnish the main channel with water from Lake Michigan, and (3) bridges to carry the various highways and railways across the main channel. No final plans have yet been adopted for these works, and only a general statement of conditions can be made.

Tail-Race.—The tail-race into which the water will be discharged from the regulating works is nothing more than its name implies—a channel which will convey the waste water into the Desplaines River. Supplementary to the tail-race channel will be the deepening and widening of the river down through the city of Joliet, Ill., so that it can take care of the water discharged from the main channel without danger of flooding the city. Altogether the tail-race channel and other improvements will cost about $2,335,000.

A possible feature of this tail-race work which has not received the official cognizance of the Board of Trustees, but which has attracted considerable study from the engineers and individual members of the Board, is the possibility of developing a very large water power from the discharge of the main channel. The available power will be divided into two reaches of about four miles each, each having a natural fall of 35 ft. The first fall will be between Lockport and upper Joliet, and the second between upper Joliet and Lake Joliet. With a flow of 5,000 cu. ft. per second, about 20,000 HP. can be developed at each fall, or altogether 80,000 HP., when the full flow of 10,000 cu. ft. per second is sent through the canal. This is, of course, the gross horse-power available. The net horse-power will be considerably less, but yet of sufficient magnitude to rank among the greatest water powers of the world. The possibilities of this power with the development of electric transmission will be readily appreciated.

Supply Channel.—The main drainage channel when flowing full has a capacity of 600,000 cu. ft. per minute, while the Chicago River, with which it connects, will furnish only about 150,000 cu. ft. per minute under present conditions. To supply the main channel with water, therefore, will require ultimately the construction of a supply channel. When the drainage channel is first opened, however, and indeed for some years afterwards, it will discharge only 300,000 cu. ft. per minute, and the engineers of the Sanitary District consider it to be entirely practicable to deepen and widen the Chicago River enough to furnish this amount without detriment to the river navigation. The improvement to the river suggested by the engineers is to dredge the river to a depth of 20 ft. at mid-channel and 12 ft. at the dock lines, and to replace some of the present bridges with structures of greater span; or where this is not possible, to construct by-passes around them. It is estimated that the cost of this work would be about as follows:

Dredging	$250,000
Constructing by-passes	450,000
Changing bridges	85,000
Dock changes	87,500
Total	$872,500

As soon as the full flow of 600,000 cu. ft. per minute is required, some additional channel will be required. Just what form this channel will take has not been decided upon, although several plans have been suggested and briefly considered. These plans have generally provided for one of two things—either taking their water from the Calumet River through a channel along the old Sag feeder to the Illinois & Michigan Canal, or else cutting a canal or tunnel through Chicago to Lake Michigan.

The chief objection to the Calumet River channel is that it would aid in no way toward purifying the Chicago River. At the same time if the city of Chicago continues building sewers to discharge into the Calumet River, the time will come when

its purification will be demanded. This is a problem which can wait solution for many years, however, while the purification of the Chicago River is of immediate importance.

In respect to the channel through the city of Chicago, either the North or South Branch of the Chicago River will probably be connected with the lake. Just which route is preferable cannot be known until the careful surveys now in progress have been worked up. From the fact that the present elevation and grade of the main channel will not purify the South Fork of the South Branch—one of the foulest parts of the river, since it takes the sewage of the stock-yard district—it would seem advisable, other things being equal, to have the channel connect with the South Fork. It is probable, however, that a channel connecting with the North Branch would be the cheaper, owing to the less improved territory through which it would pass. It is entirely probable also that the best solution of the problem will be to connect both the North and South branches with the lake. Another plan which has been talked of is to extend the North Branch to the lake at a point north of Evanston, the topography of the country being very favorable for such a channel.

All of these are suggested plans only, and until the complete surveys are worked up it is impossible to say which is the best, all things considered.

Sewerage System of Chicago.—At present the sewers of Chicago empty into the Chicago River, Lake Michigan and the Calumet River. After the drainage channel is built, there therefore remains the problem of getting a very considerable portion of the city's sewage into it. Strange as the fact may seem, the officials of Chicago do not seem to have given any thought to this question until 1895, several of the large trunk sewers planned in the two preceding years being designed to empty into the lake directly. In 1895, however, these plans were changed, and plans were also prepared for intercepting sewers to catch the sewage now entering the lake and take it to the Chicago River. Like the supply channel problem, the definite plans for the sewerage system of Chicago yet remain to be determined.

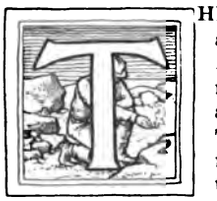
Bridges.—The bridging of the drainage channel promises some interesting problems. There will be five railway crossings and at least as many—probably more—highway crossings, all of which must be bridged. On the earth sections the clear span which will be required will be 202 ft. and on the rock sections 160 ft. With one exception, the railway bridges will be single track structures, and neither these single-track railway bridges nor the highway bridges will offer any very great difficulties from a structural point of view. The single bridge which will carry more than one track is the crossing of the six tracks entering the stock-yards. This is a skew crossing.

Although there has been much discussion by the Trustees, the exact character of the bridges to be built has not been permanently settled. It was at first decided to build swing bridges throughout, but after plans and specifications had been prepared for three swing bridges and bids received, the Trustees reversed their first decision and determined to build temporary structures only at present. A radical difference of opinion on the advisability of such action at once arose among the Trustees, and although the majority action still stands in favor of temporary fixed bridges, the question is likely to come up for reconsideration before anything is done toward actual construction.

Thus far a definite agreement for a bridge across the main channel has been made with one railway company only, the Pittsburg, Ft. Wayne & Chicago Ry. Co., which controls the six-track crossing to the stock-yards. This agreement provides that during excavation of the channel at this point a temporary trestle structure shall be built; but that within two years this shall be replaced by a permanent steel bridge of either fixed or swing span, as the Sanitary District may choose. As will be seen, this agreement leaves the way open for either a fixed or swing span solution of the bridge problem.

CHAPTER XV.

ADMINISTRATION.



HE successful prosecution of an enterprise like the Chicago Drainage Channel depends much upon a comprehensive and vital executive system. This fact was at the beginning recognized by the Trustees of the Sanitary District, and almost their first labor was to formulate rules governing their own proceedings and systematizing the duties of the subordinate officers of the District. In the following paragraphs the organization and operation of this executive system, as it now exists, will be briefly described.

The law under which the Sanitary District was organized placed the management of its affairs in the hands of a board of nine Trustees, who were empowered with complete jurisdiction in all matters. These trustees were to be elected to office by popular election by the voters in the Sanitary District, and to hold office for a term of five years. The law further provided that there should be a Chief Engineer, Attorney, Treasurer and Clerk to the District, but placed the appointment of these officers in the hands of the Trustees. Altogether the Sanitary District is one of the most independent civil corporations in the political system of this country, a corporation answerable to no other authority than the law which created it. It is a credit to its Trustees that the trust thus imposed upon them has been in no way violated. Mistakes have been made, it may be, but never has there been a smirch upon the honesty and faithfulness of their actions.

For the purpose of administration the Board of Trustees is divided into seven committees—viz.: (1) Judiciary; (2) Finance; (3) Rules; (4) Engineering; (5) Health and Public Order; (6) Federal Relations, and (7) Labor. Any question of administration coming before the Board is referred to the proper committee, which reports upon it with recommendations for such action as seems called for, but the vote of the whole Board determines the action to be taken. In other words, the system of our Federal Legislature for facilitating legislation is closely followed, but the duties of the Trustees do not stop with legislation, as do those of Congress. They are executives as well as legislators, and after legislative action is once taken they must put it into execution, and to this end proper executive departments had to be organized.

The executive departments are five in number, as follows: (1) Department of Construction; (2) Department of Law; (3) Clerical Department; (4) Treasury Department; (5) Police Department. Each of these departments is required to report regularly to the Board of Trustees on all matters relating to its particular work. The organization and work of the different departments will be described briefly.

Engineering Department.—The Engineering Department is in charge of the Chief Engineer, Mr. Isham Randolph, who is responsible only to the Board of Trustees, and for the purpose of administration, it is divided into four divisions, as follows: (1) Division of Construction; (2) Division of General Engineering; (3) Division of Maps, and (4) Division of Records.

Division 1, or the Division of Construction, is in charge of the Superintendent of Construction, Mr. Uri W. Weston, who has general charge of the work of construction, and reports each month to the Chief Engineer regarding the progress of work and the methods adopted in its prosecution. Under this division there are four subdivisions, each of which comprises the work on a portion of the channel, and is in the immediate charge of a Division Engineer, who has under him the necessary instrument men, computers and assistants. The importance of the work of the Construction Division is sufficiently emphasized by the articles which have preceded. It is upon the estimates of the division engineers that all money for construction is disbursed, and through their reports that the Chief Engineer is kept informed on all details of progress, equipment and management of the work. Estimates of excavation are made twice each month, and the contractors are paid on these estimates.

Division 2, or the Division of General Engineering, is in charge of Mr. Thos. T. Johnston, Assistant Chief Engineer. The work of this division is quite varied, and includes the preparation of plans for structures, the calculation and determination of all questions pertaining to the hydraulic problems met with in the work, surveys and estimates for all work to be done, the testing of material,

flood measurements, etc. The field work of the division is in charge of Mr. A. C. Schrader, Assistant Engineer.

Division 3, or the Division of Maps, is in charge of Second Assistant Chief Engineer Edgar Williams, and here all the maps pertaining to the work are prepared, and computations of lands taken for right of way made.

Division 4, or the Division of Records, is in charge of the Record Clerk, Mr. Wm. Trinkaus. Its duty is to keep all the records, accounts, correspondence and documents of the engineering department.

While each division is in a certain sense independent of the others, they all work in harmony for the best interests of the department as a whole. The total force employed of course varies somewhat from month to month, but a fair average is probably about 130 men.

Law Department.—The duty of this department, as its name indicates, is to administer the legal affairs of the Sanitary District. The chief officer is the Attorney of the Sanitary District, who is assisted by an Assistant Attorney and such clerks as are necessary. Mr. George E. Dawson is the present incumbent of the Attorney's office. To the Law Department are referred the various claims and demands which are constantly being made; claims by owners of property adjoining the right of way of the District for damages to land; claims by contractors for reclassification of material, for work claimed to be extra, for profit for work called for under the contract, but which the District does not admit, and a great variety of others. The department is also called upon to collect and sift the evidence in all complaints made by employees, suppliers of material, machinery, etc., who request the intervention of the District toward the settlement of the disputed matters. Routine matters of this character occupy much the greater share of the department's time, especially at present, when questions of right of way have been nearly all settled.

At first the most important work of the department was the acquirement of the right of way. Of the total 6,453.63 acres of land secured up to Jan. 1, 1895, 2,285.66 acres had to be obtained by condemnation. As the right of way was made up by the aggregation of numerous small tracts having different owners, the number of condemnation suits was very great, and the work entailed correspondingly large. The usual disposition of landowners to make the most of a good thing in cases of this kind was, of course, encountered, but, on the whole, this extortion was kept down pretty well. The total cost of the 6,453.63 acres of land secured at the end of 1894 was $2,371,856.60, or an average of $367.50 per acre.

Clerical Department.—This department is in charge of the clerk of the Sanitary District, Mr. Thos. F. Judge, and, as its name indicates, it has for its duties the general clerical work of the District.

Treasury Department.—The head of this department is the Treasurer of the Sanitary District, and its duties are to receive and disburse all money on the order of the Trustees.

Police Department.—The employment of from 5,000 to 8,000 men by the contractors of the Drainage Canal naturally collected the usual crowd of vicious and idle persons who always flock to live off the improvidence and vice of the more ignorant working men or by petty theft from their employers and the surrounding population. Saloons, brothels, dance halls, etc., sprang up along the work like mushrooms, all bidding for the money of the canal laborers, and crime and disturbance quickly resulted. To protect persons and property from interference by these people, a thorough policing of the work and adjacent neighborhood was necessary, and on July 12, 1893, the Board of Trustees exercised the powers granted them by the

Fig. 101. Sanitary District Police Station at Lemont, Ill.

drainage law, and passed an ordinance creating a police department. This ordinance provided for the appointment of a marshal, who should administer the affairs of the department under the direction of the trustees, and Mr. Edward Williams was appointed to this office.

As now organized, the police force consists of a Marshal, First Sergeant, five Sergeants, 40 patrolmen and a watchman, driver and hostler. This force is distributed over the six districts, as follows:

	Station.	No. men.
1st district,	Hymen Ave. and Ill. & Mich. Canal...	8
2d "	Summit	7
3d "	Willow Springs.....	7
4th "	Sag Bridge.....	9
5th "	Lemont	8
6th "	Romeo	8

The First Sergeant is stationed at the central

office at Sag Bridge, and one Sergeant at each of the other stations. The first and sixth districts each cover about six miles of the canal, and the other four about 4½ miles each.

Each district has a station house provided with living and office accommodations for the men, and having an iron cage in which persons arrested are confined until removal. Fig. 89 is a view of the station at Lemont, Ill., and the others are exactly like it in construction. The accommodations for the men are plain but serviceable, and the station houses present a neat appearance. The men are uniformed in dark blue, with dark drab helmets, and have the usual equipment of metropolitan police for enforcing authority. Eight horses and four patrol wagons are used for conveying obstreperous prisoners and for other necessary purposes of the department.

The work of the police department is quite varied. A population of nearly 8,000 people lives upon the work, and machinery and tools to the value of some $2,000,000 are exposed to damage in case of a serious disturbance. As few of the contractors employ watchmen, this plant has to be watched constantly. The railways paralleling the work are patrolled, and incoming trains are watched to ascertain what vicious characters find their way into the District, and to prevent annoyance to passengers from such people. This is an important part of the work. Freight trains have been taken from tramps; obstructions have been repeatedly removed from the main tracks, and fires on the railways' right of way have been extinguished. Besides this class of duties there are arrests to be made for the crimes and disturbances which occur daily. Assault, drunk and disorderly conduct, carrying concealed weapons, vagrancy and theft are the common offences, although the more serious crimes of murder and robbery are not infrequent. In 1894, 14 arrests were made for murder and 57 for burglary and robbery. It is a good commentary on the efficiency of the force to say that in 1894 only two serious crimes were committed for which the perpetrators were not arrested.

Labor, Wages and Cost of Living.—While not a part of the administration system proper, the character of the labor, the wages paid and the general welfare of the laborers have been closely watched by the Board of Trustees, and largely through their influence the payment of labor on the channel has been considerably above the general market price. Not only have fair wages been secured, but the wages of all classes have been raised to a common standard, the Italians and Polanders being paid the same as the other men, and the importation of cheap labor prevented. For the most part the contractors have showed a disposition to meet the wishes of the Trustees in paying fair wages and treating their men justly.

A great variety of nationalities are represented among the common laborers, but the mechanics, machinists and other skilled laborers are nearly all American-born citizens. Colored laborers are worked on a number of sections, generally in small proportion to the whites, and when properly managed have proved efficient. Their greatest fault is their reluctance to work more than a part of the time, and a quite general refusal to live in common boarding barracks. They prefer to live together in small parties, lodging in separate shanties and small boarding-houses. The white laborers are mostly Irish, Swedes, Austrians, Italians and Polanders, very few Germans and Anglo-Americans being employed. Like the negroes, they are disinclined to work steadily. Indeed, a large proportion of the common laborers do not pretend to work more than just enough to earn their meager living expenses, and they come and go as it suits their convenience. It is curious to note that this class is composed mostly of native-born men, the immigrants generally attempting to work steadily. All nationalities work together, and without race wars or much trouble other than an occasional free fight.

All but a comparatively small number of the employees on the canal are paid by the day, the average wages running about as follows:

Laborers	$1.50 to $1.75	Firemen	$1.75
Teamsters	1.50 " 1.60	1st levermen	2.20
Drillers	1.75 " 2.00	2d levermen	1.50
Trainmen	1.75 " 2.00	1st hookers	1.75
Channelers	2.50 " 3.00	2d hookers	1.50
Blacksmiths	2.50 " 3.00	Riggers	2.25
Machinists	2.00 " 2.50	Cableway repairers	2.25
Carpenters	2.00 " 2.25	Boiler makers	3.50
Stonemasons	3.50 " 4.00		

The salaries of the men employed by the month average about as follows:

Superintendents	$100 to $150
Timekeepers	50 " 100
Bookkeepers	60 " 125
Foremen	60 " 80
Pumpmen	50 " 80
Electricians	75 " 90
Civil engineers	90 " 100
Steam shovel engineers	125 ...
Steam shovel cranemen	90 to 100

During the summer months of 1895 about 8,700 men were employed, of which 1,700, or 19½%, earned $2 per day or more, and 7,000, or 80½%, earned from $1.50 to $1.75 per 10 hours. For shifts longer than 10 hours the men are usually paid pro rata for the extra time.

The number of men employed and the sparse population along the line of the canal for most of its length, make the securing of board for the workmen in farmhouses or villages out of the question. Most of the contractors have erected boarding barracks or camps on their work. Sometimes the contract is let to outside parties to run these camps, but many of the contractors have a commissariat department of their own. Board in the camps is from $4 to $4.50 per week. About two-thirds of all the employed men—mostly single men—board in the camps. The married men live with their families in huts, cabins, tents and cottages along the channel, paying a mere nominal rent to the contractors who erected these dwellings. Neither from these rentals nor from the boarding camps do the contractors make any money.

On most sections there are commissary stores

for the accommodation of the working men, where they can get tobacco, clothing, boots and whatever else they usually require. These are not, however, truck stores, such as have been prohibited in Pennsylvania and other states. The workmen need not buy there in order to keep their jobs, they are not charged more than in ordinary country stores, and they can buy on credit for themselves and family.

Most of the contractors have arrangements with certain hospitals by which their employees are treated in case of sickness or accident, each employee being required to contribute 50 cts. per month to the hospital fund, and in return for which he is treated free of all expense. In some cases regular physicians are employed by the contractors. As a general thing the health of the men is good, although bruises, sprains and sometimes more serious accidents occur daily.

Despite the good wages and the reasonable cost of living, the laborers save little money, the more ignorant of them being extremely improvident and childish in their expenditures. No small proportion of their surplus earnings goes into the liquor saloons, gambling houses and other vicious places, although it would be a mistake to say that the laborers as a whole are habitual frequenters of such resorts.

CHAPTER XVI.

CONCLUDING DISCUSSION.

N bringing to a conclusion the series of articles* describing the machinery used and methods of work adopted in constructing the Chicago Drainage Channel, it seems desirable to summarize some of the more salient features of the work, which have to a certain extent been lost sight of in the mass of detail relating to individual machines and methods of excavation. Broadly classified, the main problems to be solved in constructing the drainage canal were in character and order of occurrence about as follows: (1) Selection of route and determination of the most economical cross-section; (2) control of Desplaines River and exclusion of its floodwaters from the main channel; (3) excavation of 28 miles of main channel; (4) design of works to deliver and control discharge of 10,000 cu. ft. of water per second to the Desplaines River; (5) construction of supply channel to furnish water for main channel from Lake Michigan; (6) railway changes, bridges, and minor works. The character and extent of all of these problems have been reviewed in the preceding articles as far as the progress of the work would permit, but the work of construction has called for the most particular attention. The reasons for this are plain upon a little study.

To a greater extent, perhaps, than on any other large waterway, the engineering difficulties on the drainage canal have been due to the vastness of the undertaking; the mere magnitude of the physical changes to be brought about. It is true that questions of design, and often intricate ones, have come up, but the great problem of the work has been a constructional problem—a problem of how to dig quickly and cheaply a channel through miles of earth and rock, and not a problem of how to design a channel which would drain the Chicago River when once dug. Put in homely words, it has been a problem of how to do work, rather than of what work to do. This distinction does not detract at all from the credit of the engineers who have wrought out the channel, but it is a distinction which should be fully understood. The canal is the work of the engineer as a builder.

For the purpose of reviewing the work the excavation naturally divides itself into three classes: (1) wet excavation in earth; (2) dry excavation in earth, and (3) rock excavation. The amount of each class, while impossible of exact determination, is about as follows:

Wet excavation in earth	4,500,000 cu. yds.
Dry " " "	23,000,000 " "
Rock "	12,000,000 " "

For the wet excavation in earth dredges have been used, their construction and operation depending upon the nature of the material to be removed. On the two easterly sections of the canal the material to be dredged was a stiff brick clay, sometimes mixed with loam and sandy soil. Here dipper dredges were used, and under unfavorable conditions have averaged for that part of the work now finished about from 40 to 80 cu. yds. per hour. On special runs, with favorable conditions, these dredges have excavated from 75 to 155 cu. yds. per hour, and it seems fair to assume that with the work fully opened, they may be expected to average fully 80 cu. yds. per hour day after day.

Besides this stiff clay there have been considerably over a million cubic yards of soft muck taken out with dredges. This muck formed the bed of the Desplaines River, and existed in a layer varying from 2 ft. to 15 ft. thick, overlying a hard material. For this work hydraulic suction dredges similar to those so extensively used on the Pacific coast have been employed, but they were much smaller than the powerful machines which have made the enormous records of output in California and Washington (Eng. News, Aug. 4, and 11, 1892). With one exception, these dredges did very good work, considering their small size. Pumping through from 1,500 to 3,500 ft. of pipe, they have averaged about 170 cu. yds. per hour. The

* These articles began in Engineering News May 16, 1895, and appeared weekly, with slight interruption, until the issue of Oct. 3, 1895. The two final articles, describing the controlling works appeared in the issues of Nov. 21 and Dec. 12.

exception mentioned was the water jet dredge in which the usual construction of a revolving cutter to break up the material was replaced by a number of powerful jets of water. This dredge recorded a failure, never showing a sustained capacity of more than 35 cu. yds. per hour. The failure was largely due to the water jets, which, while they broke up the muck well enough, drove it away from the action of the suction pipe, so that instead of being sucked out, it merely floated away to settle elsewhere. The point well illustrated by this experiment is that the least possible disturbance of the material sufficing to bring it rapidly within the power of the suction, is what is wanted. Aside from the single powerful current entering the suction pipe, the less the water is disturbed the better, and this is where the revolving cutter has shown its superiority over other devices tried.

It will be noticed that the endless chain bucket or ladder dredges, so much used on the seaboard, were not employed here at all. In other words, the systems of dredging common on our inland lake and river works were adopted. On the Manchester and the North Sea & Baltic canals ladder dredges were used to the exclusion of almost all other types. No dipper dredges were employed on these works, and only a few hydraulic suction dredges, although much of the material, especially on the Baltic Canal, was well adapted for excavation by the last type of dredge. Another peculiarity which distinguished the dredgework on the European canals from that on the drainage canal was the enormous labor entailed in getting rid of the dredged material. On both the Manchester and Baltic canals the greater part of the dredged material had to be loaded into scows, and then the scows unloaded into cars hauled by railway. The machinery for transferring the scowloads was in many cases very elaborate and expensive. In respect to the easy disposition of the material, the work on the drainage canal has been particularly favorable, the spoil for the most part being dumped on the adjacent banks of the channel and generally within a few hundred feet.

This close proximity of the dumping grounds has influenced the methods of excavating in dry earth still more than it has the dredgework. The dry excavation in earth on the drainage canal has usually consisted of two processes: (1) the excavation of the material from its original bed, and (2) conveying the spoil to the dumping ground. For the excavation in hard material steam shovels have been used almost exclusively, and the work they have been called upon to do has been very severe. Not only has much of the material been of a very intractable character, but the work has been continuous, many of the contractors working their shovels day and night, with little delay, except for necessary repairs. The output of these shovels has been given in considerable detail in the preceding articles, where the character of the material and conditions of work were fully described, but a few general figures may be given here. In stiff clay weighing about 3,000 lbs. per cu. yd., the average output has been from 50 to 70 cu. yds. per hour; in very hard clay, thickly filled with boulders and requiring blasting, the average output has been from 25 to 35 cu. yds. per hour for the hardest and from 30 to 40 cu. yds. per hour for the medium material; in the cemented gravel, requiring blasting, the output has run from 25 to 50 cu. yds., depending on the hardness; and in handling blasted rock the output has been from 25 to 30 cu. yds. per hour. These figures indicate good average work, neither especially heavy runs nor very poor runs, due to special conditions, being considered. On the Manchester Canal, in England, the steam shovels used averaged 70 cu. yds. per hour in light soil and 45 cu. yds. per hour in clay, according to the best available records of that work.

The various forms of conveyors used to take the excavated material to the spoil bank are in all but a few instances modifications of an inclined plane, up which cars singly or in trains are hauled from the pit to the dumping ground. The exceptions to this system are the continuous belt conveyor and the continuous pan conveyor, neither of which has proved so efficient under all condition of weather and work as the simpler method. It is somewhat curious to note the very universal adoption of this, the oldest means of overcoming a vertical lift, in these days of powerful and speedy hoisting machinery, but a study of the conditions will show that it was the most suitable, as well as efficient, method that could have been adopted. The capacity of the steam shovels to excavate the material has in nearly every case limited the output, and no system of belt or bucket conveyors could have carried these intermittent loads as economically as the car and incline system. Another thing which has contributed to the use of cable inclines is the location of the dumping grounds close to the edge of the canal. As soon as the length of haul becomes much over 1,000 ft. the locomotive is more economical than the incline with a stationary hoisting engine, and we consequently find this classification of motive power on the canal work, according as the haul is long or short.

When the inclines with stationary engines were used, this limitation of haul necessitated the occasional movement of the incline closer to the work. Two means of accomplishing this movement were adopted on the canal work. Where the banks of the channel were naturally level, and required but little grading for tracks, the inclines were mounted on wheels or rollers, and kept close up to the work of excavation, the length of track in the pit being kept at the minimum at all times, but where the canal banks were not adapted to this nearly continuous movement of the incline, the practice was to move the incline (generally by abandoning the old structure and erecting a new one) only when the maximum economical distance

of haul was reached, the cars being brought to the advancing excavation by gradually extending the tracks in the pit. The relative advantages of these two methods were determined by the conditions. The determining condition on the canal has been, as a matter of fact, the location of the spoil area and the natural advantages of the bank at any particular point for the cheap construction of a track for the incline.

The traveling inclines used on the canal were more costly to construct at first, and entailed the cost of the track on which they ran, which might be very expensive on uneven or swampy ground. The advantages in their favor were minimum distance of haul and minimum amount of track in the pit; moreover, the same incline was used from the beginning to the end of the work. The stationary inclines were very inexpensive—generally being a simple earth embankment or rough timber structure—but had to be reconstructed several times; they necessitated very much more track in the pit and a constantly increasing length of haul until the economical maximum was reached, and finally they required the use of auxiliary power in the shape of teams to haul the cars in the pit and on the spoil bank. The cheap removal of the spoil was the object of the contractors, and by integrating the various factors just mentioned with this object in view, each contractor determined the style of incline, fixed or traveling, which he used.

In what has just been said, no mention has been made of the effect of the nature of the material excavated upon the relative economy of the fixed and traveling incline, but it is obvious that this may have an important influence. For example, it has been stated that the capacity of the inclines or conveying process has in nearly all cases been limited by the capacity of the excavating plant. Now, the capacity of the excavating plant, always steam shovels, is directly controlled by the hardness of the material. In other words, the softer the material, the more closely the capacity of the excavator approaches the capacity of the conveyor, for the latter is constant for any particular plant, whether the material is hard or soft. Owing to the much shorter and more rapid haul, the traveling incline has a greater capacity than the fixed incline, which makes it especially adapted to soft earth excavation. It is important to note that on those sections of the canal where the excavation is softest the banks are best adapted to the use of the traveling incline. As a mere matter of fact, the use of the traveling incline on the canal has been determined mostly by the character of the bank and the location of the spoil bank, the character of the excavation cutting a less important figure. Other comparisons between the relative advantages and disadvantages of fixed and traveling inclines for the canal work might be made, but those noted cover the principal points.

From a structural point of view, the incline with the stationary hauling engine is a more impressive form of conveying process than the incline with locomotive engines, but the latter system has important advantages where the haul is long, and when well managed has been able to compete on the canal work with the cable incline in economy. Owing to the much larger masses or units to be moved, the extensive track system, and other inherent peculiarities of the system, the element of good management enters into its success considerably more than it does in the case of the cable incline. This is a fact difficult to demonstrate by such figures of the canal work as are available, but it stands out prominently to one who watches carefully the actual work.

Before leaving the consideration of earth-conveying system in use on the canal a few words need to be said regarding the two continuous conveyors used. The more successful one was the continuous rubber belt conveyor. This conveyor, however, was considerably affected by the weather, rain and frost causing trouble, and moreover it involved necessarily a third handling of the material between the excavation and the conveying, since the earth had all to pass through a granulator to get in shape to be carried by the belt. This introduced a third set of machinery to repair and maintain. The continuous pan conveyor showed its ability to carry the material, but the first cost and the cost of operation were so great that an immense amount of material had to be handled per hour in order to make it economical as compared with more simple devices, and no satisfactory method was found to excavate and load this material. The system of power plows designed for the excavation and loading could not be made to work satisfactorily in the hard clay, and here the machine failed.

It is probable that the hardness of the material would have likewise prevented the success of any device like the continuous bucket excavators, so much used on the Manchester and the Baltic canals. In a hard, boulder-filled earth the steam shovel has peculiar advantages which no continuous moving, scraper-acting excavator possesses. A human intelligence directs the dipper through the craneman, and when a boulder is encountered which cannot be torn out at once, it can be undermined and loosened by intelligently manipulating the dipper. This flexibility of the excavating tool is not had in the continuous bucket excavator. As an example of this fault of the scraping tool, the scraper used to handle muck on Section 6 may be mentioned. This scraper was a success in the muck, but failed entirely when the boulder-filled glacial drift was encountered.

Turning now to the rockwork, it will be seen that here, as in earth, the work consisted of two processes—viz., the excavation proper and the conveying of the spoil from the pit. The excavation process consisted in all cases of channeling, drilling, blasting and loading, and the methods of doing these different parts of the work were nearly

the same on all sections. The channelers were self-contained machines, each generating its own power for locomotion and for operating the cutter. On the work as a whole the channelers averaged from 8 to 10 sq. ft. of cut per hour at a cost of from 8 cts. to 25 cts. per sq. ft., depending upon the character of the rock and conditions of work. The approximate average cost of channeling for the whole work was not far from 17 cts. per sq. ft., or about 6 cts. per cu. yd. of rock excavated. On all but one section, where steam was used, the drills were operated by compressed air, piped from central compressor plants. Despite the very considerable first cost of the central compressor plant, it has proved its economy and efficiency wherever used. The cost of drilling has run from 7 cts. to 15 cts. per cu. yd. of rock excavated. Dynamite has been the explosive most extensively used, and nearly always the blasting process has been to break down a breast extending transversely across the channel. A row of skips or cars was then strung across the canal at the front of the breast, and the broken rock loaded by hand.

This extensive use of manual labor in loading the rock has made the element of management and superintendence a more important factor in the rock work than it was in most of the earth excavation. Generally from 35 to 45 men were worked loading on each breast, and the output depended very largely upon the ability with which these men were handled to prevent "soldiering," delay in getting the skips or cars in place, interference of the men with each other and a dozen other things which the managers of labor will understand. The better measure of the efficiency of any system of work in rock is therefore the output per man per hour, and not the output per day from the breast worked, and this method of comparison has been used in the description of the rockwork.

The methods of conveying the material from the pit which were most used were the stationary cable incline, the Lidgerwood traveling cableway and the Brown cantilever hoist, fully five-sixths of the rock having been handled by these methods. The output per man per hour with these different methods has been about 0.7 cu. yds. for the incline and 1 cu. yd. each for the cableway and hoist. In each of these systems the mass to be moved is practically confined to the weight of the rock and the car or skip in which it is carried. In other words, nearly all the power expended is applied to moving the material which pays. In the great double-boom derricks used on certain parts of the work the contrary is the case, and they worked at a corresponding disadvantage. The efficiency of the cable incline is particularly notable when the cost of the plant is considered in comparison with that of other conveyors. Its disadvantage lay in its slowness of operation and the large amount of manual labor required in handling the cars after loading. In these respects the cantilever hoist and traveling cableway excelled all other devices. The cantilever crane especially was remarkable in the quickness of its operation and mechanical handling of the skip when once loaded, and notably in its rapid movement along the work.

The cantilever hoist, derricks and inclines for handling rock were all well-developed systems for handling heavy materials, like coal and ores in fragmentary masses, and very few modifications had to be made to adapt them to the canal work. With the cableway the case was different. This machine had, indeed, been long used, but never where its frequent movement with the progress of the work was necessary, nor where the load was of no value, and the prime essential of its conveying was to get rid of it in the quickest possible way. As a consequence the traveling towers and the mechanism for dumping the load in mid-air without stopping the skip were distinctly novel modifications of the cableway as it had been known, which owed their development to the necessities of the canal work. This is all the more noticeable since very few of the appliances used on the canal are really new inventions developed by this particular work, although the resurrection of old appliances, improving their construction and operation, adapting them to new conditions and combining one with another to make a new machine, are to be noticed everywhere.

The salient mechanical features of the drainage canal work have been covered, although very briefly, in the foregoing paragraphs, and in the descriptive articles—of which this is a review—these features will be found explained in detail. It is a pretty good proof of the success of the methods adopted that the nearly 40,000,000 cu. yds. of unusually hard earth and solid rock excavation is being done at a cost of 28.94 cts. per cu. yd. for earth and 76.31 per cu. yd. for solid rock, including contractors' profit. While these figures may appear large compared with those of foreign canal work, it must be remembered that in no foreign canal, except the Corinth, has the material been so hard throughout, and in no foreign canal work have the wages of labor been so great. As a matter of fact, it is probable that if the work was to be let again, it would be contracted for at considerably lower prices than it was this time.

It would be hardly proper to conclude without some reference to the purpose for which the drainage canal is being constructed. Primarily the purpose of the canal is to purify the sewage-laden waters of the Chicago River and prevent their outflow into Lake Michigan to pollute the water supply of Chicago, but secondarily its promoters had in mind its use as a part of a deep waterway to the Gulf of Mexico. Indeed, it is probable that in the minds of some of the canal's most energetic promoters the waterway feature of the work was placed foremost. Without any expression upon the advisability or inadvisability of the nation's constructing a deep waterway from the Lakes to the

Gulf, it is evident that a very considerable portion of the cost of such a work has been paid for when the drainage canal is completed. The construction of the canal has practically determined the route—viz., the Desplaines-Illinois-Mississippi River route—which any future waterway between the Lakes and the Gulf must follow. The deep-waterway feature of the canal is, however, a question which may be safely left to the future, but its proper handling, to develop best its usefulness as a sanitary work, calls for immediate attention.

Unfortunately the city of Chicago years ago committed the mistake of emptying many of its sewers directly into Lake Michigan. This may have been a natural enough mistake, but a mistake it certainly was, and that city is just now discovering it to the tune of the many hundreds of thousands of dollars which the construction of intercepting sewers to empty into the canal will entail. But whatever the cost may be, these intercepting sewers must be constructed, and the time is none too soon for the work to be begun. The recent alarming increase in typhoid fever in the city shows that there will be no safety until all the sewage is cut off from the water supply. This sewer work devolves entirely upon the city of Chicago, and is not a part of the canal work proper, as controlled by the Trustees of the Sanitary District.

Another feature of the canal work, which has nothing to do with its sanitary usefulness, but which is deserving of serious attention, is the possible development of water power at the west end of the canal. The engineers of the Sanitary District assert unofficially the feasibility of developing 80,000 HP. within a stretch of a few miles between Lockport and Joliet, and by electric transmission the larger part of this can be made available for electric lighting or power in the city of Chicago. Until reliable estimates are made of the cost of developing this power, it is little use to speculate upon the possible income from it, but it would seem to be a question well worth looking into. It may prove a means of reimbursing the taxpayers for a part, at least, of the money expended in constructing the Chicago Main Drainage Channel.

APPENDIX A.

EARTH CONVEYOR ON SECTION A.

As has already been described, the route of the main drainage channel occupied the old bed of the Desplaines River for the most part of contract Sections A and B, and the excavation was done partly under water and partly in the dry. Forming the bed and banks of the river there was a bed

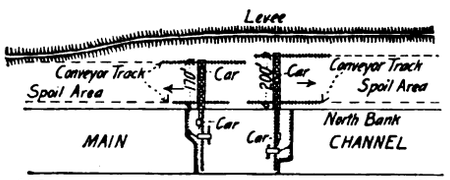


Fig. 102. Sketch Plann Showing Method of Excavation on Section A.

of muck overlying a stratum of hard glacial drift. This muck was excavated under water by means of hydraulic suction dredges, but to take out the hard material the channel was pumped dry and steam shovels and other methods of dry excavation adopted. The methods of dry excavation on Section B presented nothing unusual, but the conveyor and excavating system adopted on Section A were in a great degree different from the methods used on the other earth sections.

The contractors for Section A, Heldmaier & Neu, sublet the work of excavating the hard material to Shailer & Schniglau, of Chicago, Ill. This firm began the installation of their plant early in the Summer of 1895, but it was not until the Winter of that year that it had been put in active operation. Meanwhile a large amount of material had been taken out by means of cable inclines and other simple methods, and had been used to grade a roadway for the conveyor, which was erected later.

To understand best the conditions encountered and the system of work adopted, reference should be made to Figs. 102 and 103, showing a sketch plan of the channel and the general construction of the conveyor, respectively.

The spoil was required to be dumped on the north side of the channel, and between it and the levee, cutting off the river diversion channel. This levee was quite near the main channel at its west end, but gradually drew to the north and away from it toward the east end. (Fig. 102.) Moreover the natural surface of the north bank, A B, Fig. 103, had to be raised and the revetment to the left of A put in, to prevent the muck A B from squeezing into the channel. The specifications required that this revetment should run from C to D with a slope of 1 in 2, and from D to E with a slope of 1 in 10. The surface C, D, E had to con-

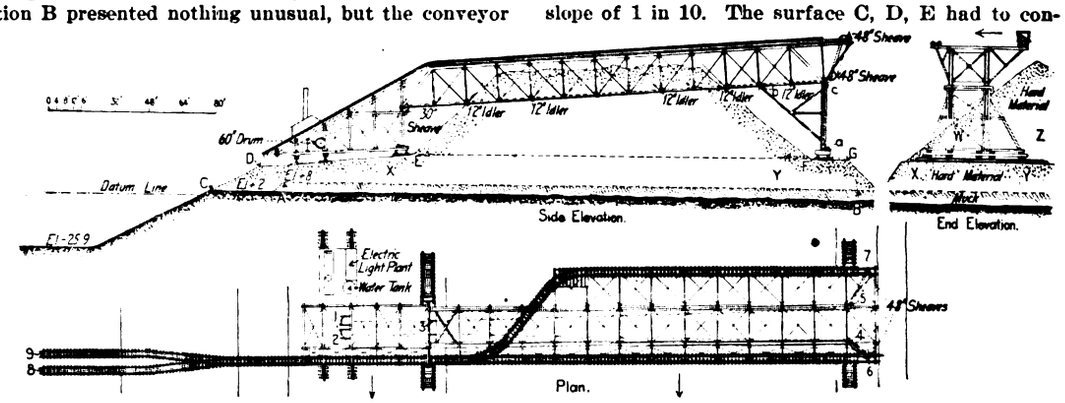


Fig. 103. Special Bridge Conveyor for Use on Section A.
SCHAILER & SCHNIGLAU, Chicago, Ill., Contractors.

form to certain requirements therefore, and any system of conveyor adopted had to take this into consideration. It also had to be considered that in order to haul a conveyor over the muck bed A B a roadway of hard material had to be built in advance.

These in brief were the conditions to be met, and

to meet them it was decided to adopt a special form of bridge conveyor and to build two; one to work from the middle of the section west, and the other from the middle of the section east. Owing to the approach of the levee to the edge of the canal at the west end of the section, the conveyor working west was made shorter than its companion working east, but the method of operating both is the same. The first step was to take out enough hard material to furnish a foundation upon which to build and start the conveyors. By cable inclines and other simple means of excavation a hundred feet or so of hard material was placed so that its surface followed the line C, D, E, F, G, (Fig. 103), and the conveyors erected on this foundation. The general form of the conveyor is clearly shown by the drawings. It will be seen from the section and plan that the earth is dumped over the overhanging edge on either side. Now in operation the conveyor is moved along the canal in the direction shown by the arrows. Sufficient hard material is dumped over the forward edge to make the foundation X Y, but the greater part is dumped over the rear edge to form the spoil bank W Z. As the conveyor advances it builds the solid roadway ahead of itself and throws all surplus material to its rear. The general scheme of operation now being explained, the details of the apparatus and its operation can be studied

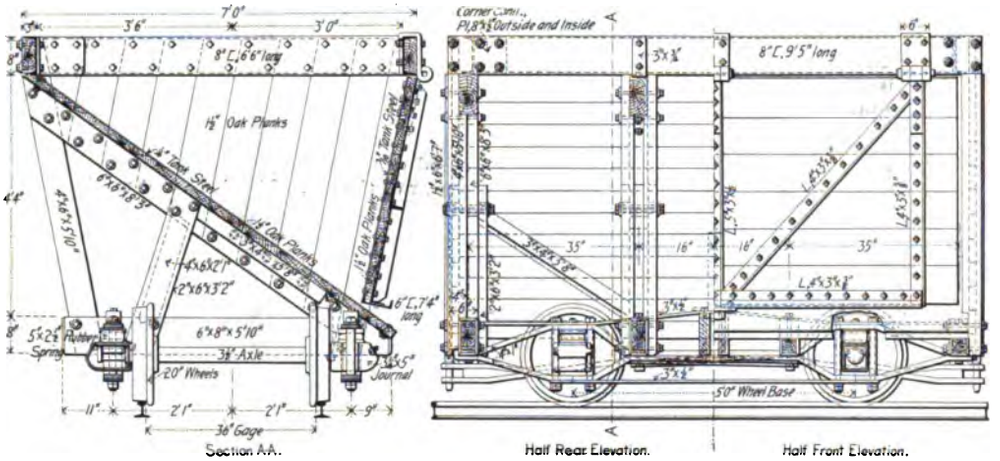


Fig 104. Special Dump Car Used on Section A.

The excavation proper is done by means of steam shovels, which make a cut transversely across the canal. (Fig. 102.) Warrington shovels made by the Vulcan Iron Works, of Chicago, are used, and it will be noticed that the trucks are swung around so that the shovel travels sidewise. The material is a hard clayey gravel filled with boulders, and the shovels have handled it at the rate of about 600 cu. yds. per ten hours without blasting.

Fig. 105. Warrington Shovel Used on Section A.
VULCAN IRON WORKS, Chicago, Builders.

The cars have a capacity of 5½ cu. yds. water measure, and two are used with each conveyor. Fig. 104 shows the construction of the car in considerable detail. The material is white oak and steel. An automatic latch provides for the rapid dumping of the car.

The general appearance of the Warrington steam shovel is shown by Fig. 105. The car is 35x10 ft. over all and is mounted on Fox pressed steel truck. All the framework is of steel, as are also the mast and crane. The turn-table is overhead and is operated by a chain from the main engine, which has 12x12-in. cylinders. A 9x9-in. thrusting engine is mounted on the crane and serves to thrust the dipper into the bank. Wherever possible wrought steel has been used in place of castings.

The conveyor consists of two combination wood and iron trusses braced together and carried by towers mounted on trucks. The front tower is practically a traveling incline, which forms the approach to the bridge, and it carries the hoisting machinery for handling the cars. The rear tower is merely a trestle bent, braced and hinged at a. b, and c, Fig. 103, and carried on five trucks. It will be noted that the car tracks are not carried directly over the trusses, but on cantilever brackets at each truss panel point, and that consequently the stresses in the tower require unsymmetrical bracing and an irregular location of the trucks.

The engine is a double 60-in. drum Webster, Camp & Lane hoisting engine, with 13x15-in. cylinders, and it gets steam from a 100 HP. boiler. Two 1-in. hoisting cables are used. One of these passes from drum 1 to sheaves 3, 5 and 7, and thence around the curve pulleys to the end of track 9. The other cable passes from drum 2 to sheaves 4 and 6, and thence to the end of track 8. A loop at the end of the cable is hooked over the pin in the drawbar of the car, which is hauled up the conveyor by the engine and is taken back by gravity. The whole conveyor is moved along the canal by a windlass.

Up to December, 1895, sufficient material had not been handled with this conveyor to determine the capacity of the system, but the contractors express their confidence that from 600 cu. yds. to 1,000 cu. yds. will be handled per ten-hour shift when everything is in good working order.

APPENDIX B.

EFFECT OF THE DRAINAGE CANAL ON THE LEVEL OF THE GREAT LAKES.

The effect of draining 600,000 cu. ft. of water per minute from Lake Michigan upon the levels of that lake and all the other great lakes to the east of it, is a question of great importance, and has been studied with some care both by the engineers of the Sanitary District of Chicago and by the United States Engineer Corps. The results of the studies of both parties have been embodied in formal reports, and these are reprinted nearly in full and discussed at some length in the following paragraphs.

Report of Board of Engineers, U. S. A.

The Board met in Chicago Aug. 12, 1895, and on Aug. 13 and 14 accompanied the officers of the drainage canal over the line under construction. Every facility and courtesy possible has been extended by the trustees and engineers of the canal for a full investigation of the subject matter. A brief description of the canal is extracted from the printed report furnished the Board by these gentlemen:

The Main Drainage Channel of the Sanitary District of Chicago is now under contract from its confluence with the south branch of the Chicago River, at Robey St., in the city of Chicago, to its southern terminus, in Will county, Ill. At the southern end of the channel the controlling works will be located. Beyond these works, the construction contemplated by the District will be the work necessary for conducting the flow from the channel in conjunction with the waters of the Desplaines River, down the declivity to and through the city of Joliet, and making such changes in the Illinois & Michigan Canal as the new conditions developed will make necessary.

The first work put under contract extended southwesterly from the Willow Springs road, and these sections were numbered consecutively Nos. 1 to 14. Average length of sections, one mile. Easterly from Willow Springs road, the sections are lettered from A to O, omitting J. The lettered sections are, except for a short distance near Summit, entirely in glacial drift, defined in the specifications thus: "Glacial drift shall comprise the top soil, earth, muck, sand, gravel, clay, hardpan, boulders, fragmentary rock displaced from its original bed, and any other material that overlies the bedrock."

The sections from 1 to 14 were put under contract in July, 1892; from A to F were put under contract late in 1892 and early in 1893; and G to M, inclusive, were contracted for in December, 1893. Sections N and O were put under contract May 2, and Section 15 Aug. 27, 1894. Earth was first broken on "Shovel Day," Sept. 3, 1892, on the rock cut below Lemont.

The Desplaines Valley is traversed by the river from which it takes its name, a stream of wide fluctuations, with no constant and reliable fountain supply. During some seasons its whole discharge would pass through a 6-in. pipe, and at others its volume reaches 800,000 cu. ft. per minute. Then it rolls majestically along, flooding the whole valley. Such being the situation, control of this stream was a condition precedent to the successful prosecution of the work upon the main channel. This control has been secured by the outlay of nearly $1,000,000 in constructing what is known as the River Diversion Channel.

About 13 miles of new river channel had to be excavated with the location of the Main Drainage Channel, and about 19 miles of levee built to divorce the waters of the Desplaines watershed from the channel which is to receive the waters of Lake Michigan and pass them on to the Mississippi River via the lower Desplaines and the Illinois rivers. The width of the River Diversion Channel on the bottom is 200 ft., side slopes 1½ to 1, grade generally 0.12 ft. per 1,000 ft.

At the head of this river diversion it was necessary to provide a safety valve in the form of a spillway, to allow surplus water to flow toward Chicago, because arrangements have not as yet been perfected for carrying the entire flood waters of the Desplaines through Joliet.

This spillway is a concrete dam capped with cut stone, and its wings faced with stone masonry; it is 397 ft. long, and its crest is 16.25 ft. above Chicago datum (this datum is referred to the low water of Lake Michigan of 1847, and is 579.61 ft. above sea level at Sandy Hook). No water flows over this spillway until the volume passing the water-gage above it reaches 300,000 cu. ft. per minute.

The cross-section of the earth sections from A to E, inclusive, is 202 ft. on the bottom, with side slopes of 2 to 1. This section extends for about 500 ft. into the west end of F, and then reduces to 110 ft. on the bottom, preserving the same side slopes. The explanation for this change of cross-section is as follows: Throughout the rock sections, and those sections in which there is a preponderance of hard material, or where rock may appear, the section adopted is designed according to law for a flow of 600,000 cu. ft. of water per minute, which means provision for a population of 3,000,000 people. The narrow channel provides for a flow of 300,000 cu. ft. per minute, or for about the present population of Chicago. The enlargement of the narrow channel can be made by the easier methods of excavation, such as dredging, whenever the needs of the city require it. The grade throughout the lettered sections is 1 ft. in 40,000 (.025 ft. per

1,000 ft.), and the bottom of the channel at Robey St. is 24.448 ft. below datum. The numbered sections, from No. 1 to No. 6, inclusive, are underlaid with solid rock. The width of the bottom, in rock, is 160 ft., and walls of masonry laid in cement will be built upon the rock surface to a height of 5 ft. above datum. Sections 7 to 14, inclusive, are in solid rock; width at bottom, 160 ft.; sides vertical, prism taken out in three tsopes with offsets of 6 ins. on each side for each cut, making top width of 162 ft.; grade in rock, 1 ft. in 20,000 (.05 ft. per 1,000).

Section No. 15 is also in rock, and its cross-section is enlarged at its south end, so as to form a "windage basin," in which large vessels may be turned around. The controlling works are located on this section. These works will consist of gates or movable dams, by which the flow of water from the main channel into the tail race, which is to deliver the outflow into the Desplaines River, can be controlled.

This river below Lockport follows the trough of the valley down a steep declivity to the canal basin in Joliet. The fluctuations in Lake Michigan, by varying slope of water surface, will be felt at the controlling works, and provisions must be made to meet these fluctuations within a range of 5 ft. above datum and 8 ft. below, or an extreme oscillation of 13 ft. The fall from datum at the controlling works to the level of the upper basin will be about 42 ft. in a distance of about 4⅛ miles. As the plans for controlling works have not been finally adopted by the Board of Trustees, they cannot now be discussed.

The total amount of excavation involved in the construction of the main channel is 26,077.765 cu. yds. of glacial drift, and 12,071.668 cu. yds. of solid rock, or an aggregate of 38,149.433 cu. yds., to which must be added the material excavated from the river diversion: Glacial drift, 1,564,403 cu. yds.; solid rock, 258,926 cu. yds.; total river diversion, 1,823,329 cu. yds.; grand total, main channel and river diversion, 39,972,762 cu. yds. All of this work is now under contract, and in addition thereto 384,958 cu. yds. of retaining wall.

In response to the request of the senior member of the Board, the Board of Trustees of the Sanitary District of Chicago has furnished a report on lake level effects on account of the main channel of the Sanitary District of Chicago, containing briefs by Trustee L. E. Cooley, C. E., and by Thos. T. Johnston, Assistant Chief Engineer, accompanied by numerous blueprints. These papers present a full discussion of the subject as viewed by the canal officials.*

What is the Outflow of the Lower Lakes?

In November, 1891, the Chief of Engineers, U. S. A., at the request of the Secretary of the American Society of Civil Engineers (who had been asked by the Chief Engineer of the Montreal Harbor Commission of Canada to suggest the subject), ordered a set of observations made to determine the amount of water flowing down the Niagara River. The time was especially propitious, as the water was then very low.

The results of these measurements were somewhat unexpected, and they were repeated in May, 1892. The second set corroborated the first, and the whole formed the subject of a report to the Chief of Engineers, which appeared in his annual report of 1893, pages 4, 364 and following. But, as the subject was important, the "Engineering News" anticipated the appearance of the official report by publishing in its issue of March 2, 1893, this report, with the permission of the Chief of Engineers. This publication was the first ever made in which, as a result of careful measurements, a relation between the level of the lakes and their outflow, or discharge, had been established and given to the public. Prior determination of this discharge had not attempted to detect this relation, and nothing more than a general determination of a season's work had been published. In all plans for the Chicago Drainage Canal, the early measurements had been taken, and those studying the subject chose such isolated figures as suited them best.

The report of 1892, being so late in appearance, long after the drainage canal was put under construction, escaped the notice of many who are interested in navigation for two reasons. Some were too busy to see anything, unless specially brought to their notice. Others thought the whole matter already fully canvassed, and settled. It is true there is nothing showing that the consent of Congress had been asked for this enterprise; certain that the subject had not been treated as an interstate affair, to say nothing of its being an international affair. The United States has always been slow to move; with its many sleeping rights, it has for many years been loth to exercise them. Not till 1888 did it begin to exercise positive legislation over its navigable waters in order to preserve them for all its citizens. Each river and harbor bill since then is found to have sections strengthening the hands of those who wish to keep the waterways open and in good order, for all classes of navigators. Not till 1890 had any prohibitive clauses been enacted into laws forbidding, for example, the destruction of channels by improper dumpings. Saw mills went their own unchecked way every year, clogging up the streams. Railways bridged all smaller streams, in the states, without interference from the United States. Many other features can be quoted. But it is sufficient to say that all that is now changed. The adopted policy is to defend, as well as improve, all water courses, now navigable, or probably navigable in the reasonably close future. Waterways are under the charge of the United States, and there is no likelihood of their being abandoned for some time to come.

With this an established fact it is impossible to think that United States supervision shall not be extended to the Chicago Drainage Canal in due time. Under whatever law built, and for whatever purpose constructed, just so soon as it is shown that that canal affects, or becomes a part of, the system of navigable waterways of the United States, some supervision or control of it must follow. When boats use it for harbor purposes; when its waters add to the Illinois River, or take from the lakes, they alter natural conditions, and the matter rises for consideration under national authority.

The water levels of the Great Lakes are very delicate. Storms, barometric changes, rainfall, even tidal changes, are felt. Records show at Buffalo no less than 13 ft. as a total possible change, between the lowest and the highest gage readings. Each lake is a basin. The water is constantly pouring in from not only one, but several inlets. The overflow, however, is now always out of the one outlet provided for that purpose; the second one, formerly at Chicago, has been plugged up.

As in our basins, when the water rises enough to take two, three or more of the small holes to carry it off, it is always to be noted that those holes are always carrying that surplus off; they do not wait until the water has time to pass from one end to the other. In the same channel the head alone governs the rate of outflow, and that head is measured by the gage-reading at the outlet. The supply of water in the

*The brief by Mr. Cooley is given on another page.

lake, the net supply, allowing for evaporation, is the sole cause of the outflow. That supply depends solely upon rainfall, but the lake, when it receives more than it has been receiving, must discharge more; when it has less, there is less to run out. If the outlet be dug down, or new ones made, the water runs off faster than it ran off before.

The outflow is instantly affected by a changed inflow, provided there is enough such to increase or reduce the head. If we have a rainfall of 1 in. over the lake area (and such are not uncommon events), there is a head of 1 in. to run off. But if there are two outlets to run out of, instead of one, this inch must run off sooner than through the one. If the new outlet should reduce the levels of Lake Michigan and Huron about 6 ins., this effect will be produced in full in about two years; it is not then a question of many years, as some suppose.

We may feel very sure, therefore, that in this question two points are certain: 1. The drainage canal is not solely a state affair, but a national one. 2. The tapping the lakes must affect their levels. But it is said, first, that the changes in levels do not concern shippers, and then that, at most, the effects will be trifling.

If one watched carefully the course pursued by shippers one would see that, as a rule, each vessel carries all that it can take, and get out of its port, or into that it intends to reach. Vessel owners and managers are very shrewd, watchful men; they know what they can safely carry, allowing for storms and short detentions arising from passing causes; they average pretty well the practicable depths, and carry all the channels will stand. They are as conversant as are theorists about the effects of storms, but they keep good watch on ruling depths. Now, should it be certain that these average depths were reduced 3 ins., or 6 ins., they must load accordingly. And not only the large boats, but also the small ones using the small harbors that the large ones cannot go into. All must lose the 3 or 6 ins., as it may be; and not for one or more trips, but for all trips, and for all time; a diminution of capacity is not a single tax, but a continuous one. A vessel that when light draws 6 ft. and loaded 12 ft. must lose 3 ins. out of 72, say 4% in capacity, each loading; a vessel drawing 12 ft. light and 20 ft. loaded would lose somewhat over 3% in capacity at each and every loading.

Should the loss of levels be 6 ins. instead of 3 ins., then these figures become doubled. Will the loss be 6 ins. or will it be 3 ins.? This is an important question, and we have only the Niagara River discharge observations from which to answer it. These cover a range of about 1.8 ft. There were scattering observations outside these limits, but the mass of results was secured between gage readings, mean lake level, the highest, and 1.85 ft. The "smooth curve" as published enables us to note the fall of 0.53 ft. on the gage per 10,000 cu. ft. per second for the first foot of fall and 0.44 ft. for the whole.

These observations, especially at the lower readings, are erratic, and indicate a need for more measurements, especially at these levels. This lower portion of the gage should be studied and additional observations made, and the Board is a unit in suggesting the importance of a series of gagings of the St. Clair River at the present time for this purpose, and to furnish additional knowledge of the relation between gage readings and discharge. The subject is of such general bearing upon the navigation of the lakes that it demands careful treatment and full data. The Niagara data do not show how much Lakes Huron and Michigan would be lowered, even if 0.53 ft. were the net loss to Lake Erie. The opinion expressed by Mr. Johnston that the effect on the two upper lakes would be some 15% greater than upon Erie would seem to point to a probable loss of, say, 0.61 ft. This possible loss of 7 ins. certainly is important enough to justify careful measurements of the discharge through the St. Clair. It is true that the law as it stands, and the intention of the trustees, contemplate the abstraction of only 300,000 cu. ft. under present conditions; but after the canal is opened measurements would not be so instructive, and we must assume that ultimately the entire 600,000 cu. ft. per minute will be drawn from Lake Michigan, as required by the state law.

The abstraction of 10,000 cu. ft. of water per second from Lake Michigan will lower the levels of all the lakes of the system except Lake Superior, and reduce the navigable capacities of all harbors and shallows throughout the system to an extent that may be determined, if at all, by actual measurements only. Under the laws of the United States these changes in capacity cannot be made without Federal authority, and to enable the executive officers of the United States to act advisedly in the matter it is necessary, in the opinion of the Board, not only that these measurements be taken, but that the money cost of restoring the navigable depths in channels and harbors be carefully estimated.

In this connection the Board submits, without expression of opinion, an estimate prepared by Mr. Charles H. Keep, Secretary of the Lake Carriers' Association, of the commercial losses in carrying capacity of the lake fleet, should a reduction be made in lake levels of 1, 3 or 6 ins.

The Board notices that the same peculiarity exhibited by the Niagara discharge curve is pointed out by Mr. Johnston as existing in the Morris, Ill., and South Branch Chicago River curves.

The Board also notes Mr. Johnston's conclusions that,

"Applying the reasoning to the St. Clair and Detroit rivers, then the value of $Q' - Q$ may be taken from the diagrams illustrating the tables before described, the only uncertainty being as to the value of a. Suppose a to be unity, and the mean depth 20 ft. Then $Q' - Q$ will equal something greater than 20,000 cu. ft. per second.

This practically corresponds with the deductions made from the Niagara River observations.

So many uncertainties arise in the application of hydraulic formulas that the only way to ascertain the approximate discharge of these streams is to measure them for periods long enough to eliminate accidental fluctuations and to cover all stages.

While the navigable capacity of all harbors and channels on the Great Lakes below St. Mary's Falls will be injuriously affected by a diminution in depth, the navigability of the inner harbor of Chicago will be diminished also by the introduction of a current therein, which, in the present condition of the river, even with the minimum flow of 5,000 cu. ft. per second, or 300,000 cu. ft. per minute, is entirely inadmissible. The estimates of the effect of the drainage canal upon this harbor should also consider this element.

The Board of Trustees have not yet determined upon a plan of treatment of this navigable channel, and their plans may be such as may improve, impair or destroy its utility as a navigable river.

All of which is respectfully submitted.

O. M. Poe, Col. Corps of Engineers, Bvt. Brig.-Gen., U. S. A.; E. H. Ruffner, Major of Engineers, U. S. A.; W. L. Marshall, Major, Corps of Engineers.

Report by L. E. Cooley, Trustee Sanitary District *

The Sanitary Canal of Chicago is now in process of construction under the authority of a law passed by the General Assembly of Illinois in 1889. This work is to be opened in 1896, or at the latest in 1897. The ultimate capacity of this channel is to be not less than 10,000 cu. ft. per second when the lake is at Chicago datum (the low water of 1847) which is 4.7 ft. below the high water of 1838 as established at Milwaukee. The law permits the channel to be developed through the earth sections on the basis of a capacity of 5,000 cu. ft. per second, provided that the same is enlarged with the growth of population to the ultimate capacity set forth, viz: 10,000 cu. ft. per second, said ultimate capacity being sufficient, in the view of the law, to so dilute the sewage of 3,000,000 people as to maintain a sanitary condition throughout the channel and in the streams into which the same is to discharge—the Desplaines and Illinois rivers.

Under the law a Sanitary District has been organized with original powers of taxation and indebtedness, governed by a Board of nine Trustees, elected by popular suffrage, and under the authority of this Board the work authorized is being prosecuted.

The work as now laid out provides for a Main Channel, which begins at a junction with the Chicago River, or rather the south branch thereof, in the southwest quarter of the city at a point 5.8 miles from Lake Michigan, by the course of the river, and extends to the vicinity of Lockport, a distance of 28.05 miles from the point of beginning, where the water is to be discharged into the Desplaines River, and such work done along the bed thereof, for a distance of 7.1 miles, as is necessary to conduct the overflow safely through the city of Joliet.

For 7.8 miles out from Chicago the channel is being constructed with a present capacity of 5,000 cu. ft. per second, the future enlargement being simply a matter of dredging through comparatively easy material. The 20.25 miles in the Desplaines Valley is through glacial drift of the most difficult character and through rock, and this part of the work is being carried out on the ultimate basis of capacity. The standard dimensions as adopted are, for 14.9 miles through the rock cut, 160 ft. wide at bottom and 162 ft. at the top, with a declivity of one foot in 20,000 ft.; and in the earth and drift for a distance of 13.15 miles, 202 ft. wide at bottom and 290 ft. at the water line when the channel is carrying 22 ft. of water, with a declivity of 1 ft. in 40,000 ft., excepting, however, the 7.8 miles at the Chicago end, previously mentioned, which are being constructed with a width 92 ft. narrower than the standard earth section.

The bottom of the channel, at its junction with the Chicago River, is actually 24.45 ft. below datum, and at the Lockport end 30.1 ft., the total theoretical declivity being 5.65 ft. The capacity is figured on a depth of 22 ft. on a conservative basis, so as to make sure of meeting any requirement of the inspectors, who are to be independent agents of the state. It will be noticed that an allowance of 2.45 ft. is made in the grade at the Chicago end in order surely to meet any solution that may be demanded through a connection with Lake Michigan, in order to feed this channel to its full capacity. These additional works have not been provided for, nor have plans for the same been matured. Should these works be carried out on a liberal basis, the depth in the Main Channel will be increased 2 ft. at low water.

It is proposed to open these works on the minimum capacity provided by law (assumed at not less than 5,000 cu. ft. per second, but actually 20,000 cu. ft. per minute for each 100,000 of population), and it is presumed that considerable work will be required in the Chicago River to pass the minimum volume without injury to navigation. Extensive works of a radical nature will be necessary to provide the ultimate volume, viz.: 10,000 cu. ft. per second, and several years will be required for their full developement.

The volume flowing in this channel will be regulated by controlling works at the lower end at Lockport, and by these means the discharge may be fixed and controlled at any amount, or entirely stopped at pleasure.

Aside from its sanitary utility, the Channel is to be regarded as the most costly part of a waterway from Lake Michigan to the Mississippi, and as a useful extension of the harbor of Chicago for vessels of deep draft, and these objects were contemplated as important incidents of the work, and were fully expressed as the policy of the state when the law was passed.

The question to be considered is the effect on lake levels of removing 5,000 cu. ft. per second in the immediate future, and ultimately of 10,000 cu. ft. per second.

Technical Consideration.

All investigations have proceeded on the basis of 10,000 cu. ft. per second, and the ultimate effect on lake levels of diminishing the volumes passing through the several outlets and connecting channels of the lake system by this amount. The effect of any lesser volume will be in direct proportion to the effect produced by 10,000 cu. ft.; in other words, 5,000 cu. ft. will produce one-half the result.

In all these inquiries the lake system is to be regarded simply as a great river, subject to fluctuations the same as any stream, according to the supply of water draining thereto. It has annually its high water period and its corresponding low water period, and in some years this low water drops much lower than others, and again, in a series of years the high waters reach a limit much higher than others, all depending upon the annual precipitation and whether rain and snowfall are deficient or excessive, and also on successions of dry and wet seasons. The range of these fluctuations is much limited over the action of normal rivers on account of the reservoir action of the enormous lake expanses; and, also, on account of their great water surfaces, evaporation, wind and other effects, are important. It is assumed, however, that whatever in any degree affects one of the lakes in its water supply, will likewise in some degree affect all the others below it, depending on the area, local water supply, and the conditions of the outlet in each case. For instance, the St. Clair River runs at a higher elevation when carrying a volume of 230,000 cu. ft. per second than when carrying a volume of 10,000 ft. less., or 220,000 cu. ft. per second, the same as any other stream, and the level in Lakes Huron and Michigan is determined by the elevation of the water in the St. Clair River. In the same manner is the level of Lake Erie determined by the volume passing through the Niagara River and the local outlet conditions in the vicinity of Buffalo and Black Rock; and that of Ontario by the volume of the St. Lawrence and the conditions at the head of the Galop Rapids below Ogdensburg. Normally, the effect should be less down the stream on account of its increasing volume; in other words, the volume of the St. Clair River is diminished

*A report prepared for Harvey D. Goulder, Attorney, Lake Carriers' Association, and also submitted by the Trustees of the Sanitary District of Chicago to the recent Board of U. S. Engineers, appointed to report upon this question.

by a larger ratio than is that of the Niagara or St. Lawrence.

In the investigations heretofore made, the mean discharge of the St. Clair River has been taken at 225,000 cu. ft. per second, and of the Niagara River at 265,000 cu. ft. per second. (On the authority of L. Y. Schermerborn, for many years assistant engineer under Colonel Roberts, and republished by Charles Crosman, of Milwaukee, in his chart of lake fluctuations.) These figures are based on the best available information collected by the lake survey. Assuming these figures to be correct, the abstraction of 10,000 cu. ft. per second will diminish the mean outflow in the St. Clair River by nearly 4½%, and in the Niagara River by about 3¾%. On lines of reasoning obvious to those unacquainted with hydraulic principles, it is apparent that the ruling depth in the rivers at mean lake level cannot be lessened by an amount greater than these percentages. Applying hydraulic principles, the effect will be only a fraction of that indicated by the reduction in volume.

The writer had the honor to lay the foundation of the present project in a report drafted for a committee of the Citizens' Association of Chicago in 1885, which was adopted by said association as the basis of promotion. His professional experience has lain along the lines of river hydraulics, and naturally the first matter to consider was the effect on lake levels of so bold a project, and this he satisfied himself of before the proposition was even suggested. In 1886-7 the matter was considered by the Drainage and Water Supply Commission, an engineering organization officially constituted to determine a plan for sewage disposal, and this commission also satisfied itself upon the subject before committing itself to the project. In January, 1888, the matter having been publicly raised, the writer discussed the question publicly for the first time in a brief, entitled "The Lakes and Gulf Waterway," now out of print. (Three editions were published, aggregating 15,000 copies.) Later in 1888-9 the matter was discussed at great length before the Western Society of Engineers by several well-known hydraulic engineers, and the discussions were published in the Journal of the Association of Engineering Societies in March, 1889. (Reprinted as a special edition of 5,000, and issued by the Citizens' Association of Chicago. In this discussion the matter included in the brief upon the "Lakes and Gulf Waterway" were republished.)

The discussion before the Western Society of Engineers may be considered as exhaustive, so far as the data existing at that time are concerned, and very little original information has been collected since. It was fully recognized that the data was inadequate for a positive determination, and the matter was approached by the several writers from various hydraulic standpoints, and the conclusions reached are to be regarded as settling limits rather than a specific amount. The concurrence of opinion was, however, most remarkable, and the actual results deduced varied between 0.2 ft. and 0.4 ft., as the probable effect of removing 10.000 cu. ft. per second through a new outlet. The effect at low water would be somewhat greater, and at high water somewhat less than at mean stage.

In 1891-2 some measurements were made of the discharge of the Niagara River opposite Black Rock. These observations indicate that the mean discharge of this river has been taken too high. They cover an inconsiderable range of lake fluctuations, there being but one low-water observation, and none much above the medium stage. These observations seem to indicate at and near low water an effect of about 0.3 ft. At medium and high stages the conclusion has been drawn that the effect would be greater. As such, deduction is at utter variance with all experience in hydraulics, any conclusions from these observations must await further measurements made at extreme low water, and also the necessary measurements at high lake, when, no doubt, the observations made will be found to indicate normal variations. These observations are printed in the report of the Chief of Engineers, U. S. A., 1893, p. 4,364. The official report ventures its inferences with proper caution, considering their singular character.

In a paper read before the Western Society of Engineers, in October last, Mr. T. T. Johnston, First Assistant Chief Engineer of the Sanitary District, concludes that no supposable condition could make the effect as great at 0.5 ft. Mr. Johnston approaches the matter largely on the basis of analogy with our large Western rivers, in the investigation of which he spent several years of professional life.

All dates and opinions up to this time seem to point to the conclusion that between low water and high water, and over a range of four feet, there is a variation in discharge of over 100,000 cu. ft. per second, and that to lower lake levels by 0.4 ft. would take over 10,000 cu. ft. per second. For the purposes of discussion the effect may be assumed at 0.3 ft. until determined by actual observations of the most painstaking character.

That there are many reasons for making these observations, in order to ascertain the effect of the deepened channels, of ship canal and water power schemes, and also for scientific purposes, is evident. When the facts are properly ascertained and valued, the effects of any given cause will reduce to a question of plain demonstration rather than of speculation.

Discussion.

The question at issue is a very sober one, the interests concerned are many and important, and conclusions are to be arrived at candidly and without distortion. If great public purposes may be attained without substantial injury to important interests, no objection should lie; and again, if injury is to occur, objection should content itself in providing the proper remedy.

It is assumed that any injury attaches to the effects produced at or near low water when the available depths for navigation are least.

It will be contended that the effects on the interests of navigation are immaterial; and further, if they be not so considered that the remedy may be easily applied. It is proposed to develop the several considerations which bear upon the question.

1. The Detroit River has been deepened at the Lime Kiln crossing from an original depth of 13 ft. to 21 ft.; the St. Clair Flats from 9½ ft. to 16 ft., with work now in progress for 20 ft.; work is in progress at the head of the St. Clair River, at the entrance of the Detroit River, and both above and below the Lime Kilns for 20 and 21 ft. The St. Mary's River had an original depth of 9½ ft., which was increased to 16 ft., and work is in progress both above and below the rapids for 20 and 21 ft. The Niagara River is having its barrier reef at the outlet of Lake Erie cut down to 21 ft. to extend deep water down to Tonawanda. The Canadians deepened the reef at the head of the Galop Rapids below Ogdensburg from 10 to 16 ft.

All these changes in outlet conditions necessarily have affected and will affect lake levels, and some of them doubtless by sensible amounts that may be greater or less than that produced by the decrease in volume of water due to the new outlet at Chicago. This question has never been raised except in relation to the Canadian improvement at the Galop Rapids, and in that case was dismissed as immaterial after a learned technical discussion. (See report of Chief of

Engineers, U. S. A., p. 2,470, et seq.)

It may be said with confidence that had the question not been raised in conjunction with the Chicago Sanitary Canal, all lake interests would have been equally oblivious to any injury that may follow: In other words, the effects are so obscure and ill-defined as to make their practical detection impossible by the ordinary commercial agencies.

2. If it were not known from technical considerations that lake levels were to be changed by 0,3 ft. (assuming that amount to be correct), it would be practically impossible to determine the fact by any measurements that can be made, or observations on lake levels continued for a century, and for the following reasons:

a. The mean annual fluctuations between the high water of late spring and early summer, and the low water of late autumn and winter is, for Lakes Michigan and Huron, 1.34 ft.; Lake Superior, 1.2 ft.; Lake Erie, 1.55 ft.; Lake Ontario, 2.07 ft. These fluctuations vary greatly in different years.

b. The fluctuation over long periods is from 4 to 5 ft., as from the high water of 1838 to the low water of 1847, a range of 4.7 ft. for Lakes Michigan and Huron, and still more to the low water of 1891-2. These fluctuations are irregular as to period, but usually pass over a range of 3 to 4 ft. every five to seven years.

c. Every change of the wind produces effects from a few tenths to extremes of several feet, depending on velocity and direction.

d. Rapid changes of barometric pressure produce sensible effects. A high barometer on Lake Michigan and a low barometer on Lake Huron can easily shift large volumes of water through the Straits of Mackinaw, and make a difference of level of one foot between the two lakes, and there are observations indicating such a result. A high barometer on Lake Huron and a low one on Lake Erie will increase the discharge through the St. Clair and Detroit Rivers, and possibly the discharge of the Niagara River may be varied from this cause.

e. There are periodic fluctuations occuring at short intervals of less than one hour, even in the calmest weather. Automatic tide gages show these fluctuations at all times, frequently of several tenths of a foot, and they are known to have much exceeded one foot.

f. The difference in evaporation, one year with another, may easily exceed the volume to be abstracted; 10,000 cu. ft. per second would remove from the combined surfaces of Lakes Huron and Michigan in one year 2.97 ins. of water, and this is only one-half the difference in evaporation for the years 1867 and 1868, as reported by the Lake Survey.

g. The excess of water required to mature a corn crop over that required to mature a crop of small grain throughout the water-sheds of Lakes Huron and Michigan would supply the Sanitary Canal several years.

Without raising additional points, supposing that observations for 20 years after the Sanitary Canal is opened, are compared with observations for 20 years previous, and it is found that the mean level during that period has stood 0.3 lower, would the evidence be conclusive? Might there not be changes in climatic conditions? May not the inhabitation of the watershed change conditions of drainage and absorption? May there not be carelessness in gage readers and changes in reference bench marks in 40 years? Are not the outlet sand shallows undergoing changes and improvements? Finally, take the records of fluctuations since 1838, nearly 60 years, and consider them carefully; are we not prepared to believe that the next 20 years will show a higher mean lake surface that the last 20, even after allowing 0.3 ft.?

If the normal changes in lake surfaces are so large and various as to obscure a specific change relatively small in amount, so that a vessel owner is obliged to employ experts and make critical scientific examinations through a series of years to ascertain if he be injured, we may relegate the matter, for practical purposes, to the purely scientific field. Under practical conditions, are vessel owners loading vessels to margins of 0.3 ft., or do they even work as close as that in ship canals where water level conditions are under control within close limits.

3. Any changes that have been made in lake levels heretofore have been the results of deeper channels, to which harbors and shipping had to conform, so it became a matter of no moment to any vested interest, and could at most have curtailed subsequent development by a very small amount. Any effect due to the Sanitary Canal, of Chicago, will occur on the eve of the opening of the new channels through the connecting shallows, and is not of importance to interests that are vested on present depths, and at most can effect prospective interests in this degree—that they will develop on a basis of 19.7 ft. and 20.7 ft., rather than 20 and 21 ft. If lake interests are to look forward to a progressive deepening of the connecting channels in the future as in the past, and an ultimate project to the high seas of not less than 26 ft., then the matter may be dismissed, as the movement for still larger depths will take effect before vessel interests have generally exhausted the provisions that are now being made.

4. Assuming that the effect will be material, the remedy therefor is to be considered. In a discussion in the "Marine Review" of Sept. 7, 1893, Gen. O. M. Poe, in charge of the work through the connecting shallows of the lakes, in reply to an article by Mr. G. Y. Wisner, Civil Engineer, advocating the control of the level of Lake Erie by means of a dam at the head of the Niagara River, pointed out the cheap character of the work required to secure greater depths, should they be found expedient.

Aside from the works already provided for in connection with the new channel at Sault Ste. Marie, the cost of securing a navigable depth of 20 ft. is less than $4,000,000, or inside of $1,000,000 for each foot in excess of 16 ft., the ruling depth for many years past. Future increase in depth will doubtless be more expensive, as the quantities of material will probably increase faster than the cost will diminish on account of improved methods.

It is sufficient here to point out that the navigable depth may be readily increased, and at inconsiderable cost as measured by the benefits. Conceding the extreme effect of the Sanitary Canal, it will add to the cost of deeper channels in the future not over 1% of the ultimate investment in the Chicago enterprise. This will be offset many times when that enterprise is completed so as to be suitable for a harbor for lake shipping without cost to the general government, to say nothing of the advantage to all lake interests that will ultimately result through a navigable connection with the Mississippi Valley.

5. In the "Detroit Free Press" of Jan. 8 and 11, 1889, appeared two interesting communications upon the effect of the proposed water power canal at Sault Ste. Marie on the level of Lake Superior. This canal proposed to take out some 10% of the volume flowing over the rapids, and it was contended that the level of Lake Superior would be reduced thereby nearly 6 ins., diminishing by that much the depths of the U. S. canal and the approaches thereto.

Gen. O. M. Poe, in his reply, deprecates any alarm to the interests of navigation, and, admitting for the sake of argument the effect alleged, says:

A simple, easy and inexpensive way of remedying the evils which the writer of the article seems to fear, would be to reduce the cross-section of the river by building a spur dam at the head of the rapids, thus intercepting an area equal to or even considerably less than the cross-section of the water-power canal; it surely would not require a construction of any great magnitude or cost, nor would it tax the ability and resources of the engineer to an overwhelming degree.

The same methods can be applied to the St. Clair, Detroit, and Niagara Rivers. It will be objected that local increase of velocity will thereby be occasioned, detrimental to the interest of navigation, but this will probably not be considered a serious matter by the official mind in view of the dyke built in connection with the deep channel through the Middle Neebish for the evident purpose of counteracting any effect which this new channel may have in lowering the water level in the St. Mary's River above, and at the Soo.

Without passing on the quality of this solution, it is sufficient to say that any ill effects can be met by narrowing the outlet channels, an adjustant that Nature itself might provide in the course of time, as it meets all abnormal disturbances of the balance of its forces.

6. A favorite project of the writer, which he has developed on former occasions, is to fully control the outflow of Lake Superior by work on the Sault Ste. Marie Rapids for the purpose of permitting a much larger supply of water to be taken from the lakes at Chicago for the purpose of improving the low-water navigation of the Mississippi River.

The high water period in Lake Superior is later than in the lakes below, and the water therefrom comes in on top, and behind to swell and prolong the high water stage. Suppose that the flow from Lake Superior were restrained during the spring and early summer, and were allowed to come out later in the season and during the winter. It is apparent that high water on the lower lakes would be restricted and the lower stages better maintained. It is estimated that by thus controlling the outflow of Lake Superior it would be feasible to remove three or four times the volume provided for in the Sanitary Canal, or 30,000 to 40,000 cu. ft. per second, without impairing low water stages or the minimum depths available for navigation.

If this proposition is feasible from a technical standpoint, then sufficient control of Lake Superior to correct any effect that may be occasioned by the abstraction of 10,000 cu. ft. per second, presents no engineering difficulties of a serious character.

7. It has been proposed to control the level of Lake Erie by a dam across the Niagara River. Such a project has been seriously advocated for some time by G. Y. Wisner, Civil Engineer, of Detroit, and the proposition was presented to the Toronto Deep Waterway Convention in September last by the Cleveland delegation and heartily endorsed by the assembly. The arguments advanced are to improve the depths at the Lime Kilns and vicinity and in the lake near the mouth of the Detroit River, and in all the harbors of Lake Erie and the approaches thereto. This project has been advocated entirely independent and apart from any considerations based on the effect of the Sanitary Canal of Chicago.

The project has great merit, and hardly needs more than a clear statement of what it is proposed to do to commend itself. If any such project is to be carried assigned to the Chicago enterprise.

out, it effectually disposes of the Chicago question; for it will be feasible to control an additional depth on Lake Erie several times any effect that can be

8. The movement for ocean navigation into the lakes that is now beginning to crystallize, and the sentiment for which was voiced by the international convention at Toronto in September last, is one which will excite a deep and growing interest throughout all the region tributary to our lakeboard, and is likely to grow in force more rapidly than any one realizes who has not made a deep study of economic factors and the engineering possibilities. When such a movement materializes into engineering forms, our lake problems will be looked at from a very different standpoint and the matter of controlling lake levels and meeting such problems as that at Chicago will take on a more purely incidental character.

9. The introduction of high powered vessels of deep draft to carry large cargo with speed will bring to the mind of practical navigators a question which has not heretofore appealed to them on drafts of 16 ft., and that is the necessity of wider channels and ample clearance beneath the keel. It will be found difficult to handle vessels in a crowded stream with only 1 or 2 ft. beneath the keel and under the influence of varying currents and winds, and that no considerable speed can be made under such conditions. It has been stated that the great Atlantic liners are unable to make their best time in less that 1,000 ft. of water, and every one acquainted with Western river navigation is familiar with the effect of an attempt at speed when the depth is small in proportion to the draft of boats. The interests of lake navigation to-day are certainly sufficient to justify channels of 24 to 26 ft., even though the harbors should be limited to 20 ft., and should an ultimate depth of 26 ft. be the future policy, the connecting channels should be deepened to 30 ft. and upwards. If any such development is to be the logical outcome of growing lake interests, the effect of the Chicago Sanitary Canal sinks into insignificance.

Conclusion.

We may conclude as follows:

1. That the data is insufficient to reach a conclusion as to the specific effect, and that the information available indicates limits not less than 0.2 ft., and not exceeding 0.4 ft., between which the final determination will lie.

2. That the magnitude and character of lake fluctuations are such that if the effects were unknown from purely scientific observations and measurements and technical analysis they would never be discerned or appreciated: in other words, lake phenomena are so active and of such amplitude that results relatively small are entirely masked.

3. That conceding any effect that may be claimed, several remedies are feasible therefore, any one of which can be applied at a cost relatively small as compared to the cost of the Sanitary Canal of Chicago, and that the expense of such application will be a small part of the benefits which lake interests will ultimately derive through that work.

4. That the future of lake interests and their seaboard connections will demand a radical deepening of the shallows of connecting channels, and a control of lake levels so that the interest in the question raised will reduce to a technical discussion in hydraulics.

5. That a careful remeasurement of the outflow of the several lakes under all conditions is desirable as the only final arbiter of any lingering doubts, and also for the more important purpose of projecting future works of a radical character and valuing the effects thereof.

The discussion has proceeded on the basis of the effect of 10,000 cu. ft. per second. It is proper to call attention to the fact that it is proposed to open the channel in 1896 or 1897 on the basis of 5,000 cu. ft. per second, and that extensive improvements of a

radical character must be made before the channel can be utilized to the full capacity ultimately contemplated, and that several years will elapse before these are fully consummated. The time will, therefore, be ample to make exact determinations and without prejudice to any material interest.

This discussion is not to be regarded as the official expression of the Board of Trustees, but rather as the individual view of one of the trustees, who was the first Chief Engineer of the District, and a promoter of the enterprise from its inception.

Addenda.

The above brief should be emphasized along the line of the amount of clearance beneath the keel, as particular stress has recently been laid on the value of small changes in depth.

The recent fleet that is built to utilize the new channels of 20 and 21 ft. is actually molded for a draft of 18 ft., and this will be substantially the maximum loaded draft. The reason is obvious: Large vessels must have some clearance in order to navigate with any freedom and safety, and 2 or 3 ft. is a small enough margin for safety, considering the obstructions that may lie along the bottom, as sunken logs, and boulders carried in by the ice; and, also, for the reason that lake fluctuations are too erratic to make a closer margin safe. Under these considerations the value of a minor change of level, such as may be produced by the Sanitary and Ship Canal of Chicago, becomes a matter of relatively small consequence through the deepened connecting channels of the several lakes.

The same conclusions apply to the harbors, only in less degree. The larger harbors will surely be deepened to meet the requirements of the new fleet. Considering dredging methods on the practical side, a small fraction of a foot partakes of a paper discrimination of little moment outside the office. The smaller harbors, frequented by boats of light draft, engaged in the lumber and coasting trade, are so much under the influence of beach movement and other deposits that it is a wise navigator indeed who can tell within a few inches how much cargo he can carry on successive trips.

The only practical rule followed is to go safe, and the margin of safety is not measurable by the limits assigned to the effect of the Chicago Canal. If it be admitted that the working draft of vessels will be affected at all, the matter is surely one incapable of practical valuation on the financial side. It belongs to the indefinite realm, like rain, dew, fog, sunshine, temperature, evaporation, etc., small margins in which are incapable of valuation in relation to material affairs, and the most that can be said is that certain tendencies make for good, while others make for bad, and that all effects are relative. In summing up the questions, positive and negative results must be considered, and a balance struck with reference to the common welfare.

Unquestionably the entire Chicago enterprise is prejudiced by the pessimistic talk against the ship canal and navigation idea. As long as the idea of a scheme of national benefit, through the connection of the lake region with the Mississippi Valley, was held out as a realizable project of the early future, the people bordering the lakes were willing to resolve their doubts in regard to lake levels in Chicago's favor, as were also the people along the Illinois and Mississippi rivers willing to waive their doubts on the sanitary side.

The reaction against this idea is of the most ephemeral character, and such as occurs periodically in the history of all great enterprises. The people of the state at large are almost unanimously in favor of the carrying out of the waterway idea on the broadest possible lines, and have fully expressed their policy in this regard through the general assembly in the "Act to promote the construction of waterways," passed June 14, 1895, in the following language:*

It is hereby declared to be the policy of the state of Illinois to procure, as soon as practicable, the construction of a trunk waterway through the state from Lake Michigan via the Desplaines and Illinois rivers to the Mississippi River of such dimensions and capacity as to form a homogeneous part of a through route from the Atlantic seaboard to the Gulf of Mexico.

This policy represents also the views of a large majority of the people of Chicago, and there is little question but what matters in connection with the Chicago enterprise will shape themselves along these lines in the near future, and further, that the state will enforce the broad view in due season.

I assume that Chicago must sooner or later meet the issue, not only on the side of the lakes, but also on the side of the Mississippi Valley, both on lake level and sanitary effects. She will have but one valid defense, and that is along the lines which sees Chicago's greatest good in the good of the state and nation.

Controlling the Levels of the Great Lakes.†

The engineering questions and legal questions which have grown and are likely to grow out of the Chicago Drainage Canal are of absorbing interest, because to a large degree they are entirely unprecedented. Never before in the world's history has any work of man been carried out that affected the water line on four thousand miles of shore. The endless contentions and disputes to which riparian rights have in all times given rise are well known, but past history has never recorded a question of riparian rights affecting so vast a territory and such a multitude of interests.

Chicago is making a new outlet for the Great Lakes, and will set flowing through it a river eight times as large as the low-water flow of the Merrimack at Lowell, and four times as large as the low-water flow of the Ohio at the junction of its two branches at Pittsburg. The ultimate flow of 10,000 cu. ft. per sec. through this channel will be in round numbers 15 per cent. of the entire outflow of Lake Michigan; it will be about 4 per cent. of the outflow of Lakes Superior, Huron and Michigan combined, and about 3⅓ per cent. of the flow in the St. Lawrence. These percentages are based on the best figures which are at present available for the discharge of the St. Clair, Niagara and St. Lawrence rivers. Future and more accurate measurements of these discharges may change the percentages by a fraction of 1 per cent. either way. They can hardly do more than this.

Supposing for the present the outflow of the Drainage Canal to be 4 per cent. of the flow in the St. Clair or Niagara river, it is manifest that their average discharge when the Drainage Canal is set running will be 4 per cent. less than it is at present. What will be the effect of this 4 per cent. reduction in outflow upon the level of the lakes? To give an accurate answer to this ques-

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* This bill was vetoed by the governor on June 26, after the adjournment of the general Assembly.

† Editorial in Engineering News, Oct. 3, by Charles Whiting Baker, Editor.

tion, an extended discussion of river hydraulics is essential; but an answer of approximate accuracy can be given by any one endowed with common-sense and a knowledge of arithmetic. If the volume of water discharged by the St. Clair River, for example, were reduced by 4 per cent, then if the width remained the same and the velocity of the current were constant, its depth would be 4 per cent. less than at present. The depth of this river, it is manifest, determines the level of Lakes Huron and Michigan. In speaking of the depth of the river reference is made, of course, to its depth at the outlet, at the point where the cross-section narrows to such a degree that changes in the cross-section have an appreciable effect on the lake levels. Suppose the average depth of the St. Clair outlet to be 20 ft. Then, as 4 per cent. of 20 ft. is 0.8 ft., the river surface at this point would be 0.8 ft. lower if only 96% as much water were flowing in it, and the width and cross-section remained unchanged.

But, as every one knows, the width of every river becomes less when its depth is reduced, and, still more important, its velocity is materially reduced. Every one who has ever seen a river, great or small, at flood stage, knows that it then flows much more swiftly than at ordinary stages. Hence we can be certain that a considerably smaller reduction in the depth of the river than that above indicated will result from a reduction of 4 per cent. in its discharge.

We have used figures in the above illustration merely to indicate the simple method by which any one, with no knowledge of engineering, can determine for himself the fact that the Chicago Drainage Canal, great as is its absolute outflow, will yet have an effect on the levels of the four lower lakes and their outlets which will be measured in inches only, and will not exceed, as the utmost maximum, 6 or 7 ins.

So much for common-sense and arithmetic. Now, what can engineering methods do in the way of a more accurate determination? The answer to this question is that with proper facilities a very accurate determination of the effect upon lake levels is possible. What is necessary is simply to measure the discharge of each lake outlet at various stages, and find the difference in level to which a variation in flow of 10,000 cu. ft. per sec. corresponds at each stage.

Thus far, however, this has not been done, and with the imperfect data at hand, engineers have estimated the effect of the canal upon the lake levels all the way from 2½ to 8 ins. Mr Cooley, in his argument in this issue, assumes the diminution of level which will be produced at 4 ins. The Board of Government Engineers, in its report, refrains from committing itself on this point, merely saying: "Will the loss be 3 ins. or will it be 6 ins.?" and concludes in substance that further gagings of the St. Clair and Niagara rivers are needed to settle this question.

When such high authority hesitates to commit itself, we shall certainly not venture to set closer limits for the fall in levels which will result from the outflow at Chicago.

But the question as to the effect of any given reduction in lake levels upon navigation interests is one that needs no river gagings to settle. It ought to be possible to reach an agreement upon it. Our readers will note a marked divergence on this point between the views of Mr. Cooley and those of the Government engineers. The former gentleman urges, first, that other changes in lake levels are being produced by the dredging of connecting channels without serious objection being raised; second, that a 4-in. reduction in levels will be so small that it would never be noticed as a practical factor in loading vessels; third, that as the shallow channels are to be deepened anyway to 20 ft. or more, they might as well be deepened the trifling additional amount necessary to offset the effect of the Drainage Canal; fourth, that the levels of all the Great Lakes might be raised enough to much more than compensate for the effect of the Chicago canal, by building controlling works at their outlets.

The Government Board, on the other hand, claims that the master of a vessel carries, as a rule, all she can take and get out of the port, or into the port for which she is bound, and hence that a reduction of 3 ins. or 6 ins. means in effect a reduction in the carrying capacity of the bulk of the lake fleet to the extent represented by 3 ins. or 6 ins., less depth of loading.

It ought to be possible to reach a closer agreement on this question. We may grant all that Mr. Cooley says respecting the difficulty of detecting an actual change in lake levels, and as to the means by which a reduction in such levels may be remedied, but it does not seem quite true that the ruling principle of vessel-navigation is, as he says, to "go safe." On the contrary, our information is that the general rule is to load vessels to the water line, provided the channels and harbors to be traversed will warrant it. Whether they will warrant it or not is determined by the experience of vessels in going aground in the various harbors or channels, rather than by assuming an arbitrary margin of safety between the vessel's draft and the published lake soundings, and fixing by that the depth of lading.

Mr. Cooley has well pointed out in his paper that the deepening of the channels to 20 and 21 ft., now in progress, will give existing lake vessels all the water they can utilize, even with the greatest supposable reduction due to the Chicago canal. We do not find, however, that he has taken into account the shallow harbors of the lower lakes, and the fact that with the new deep channels these harbors will fix the depth to which a vessel may be loaded. Apparently he looks forward to a deepening of the lake harbors to correspond to the deeper channels, but the deepening of these harbors to the greater depths proposed is bound to be a matter of great difficulty and expense.

On the other hand, the published estimates of loss to the lake shipping interests by a 4 or 6-in.

reduction in lake levels seem to us considerably exaggerated. If a careful examination were made, it would probably be found that, taking into consideration the vessels of moderate draft and the trips made by the larger vessels with partial cargoes, a large percentage of the traffic would not be affected at all by the slight reduction in levels which is proposed. Again, it is not an absolutely universal rule that cost of carriage decreases with increase of depth. If we remember correctly, the whaleback, which has proved so great a success in the grain and ore trade on the lakes, draws considerably less water than some of the vessels with which it has been in successful competition.

It seems sensible, on the whole, therefore, to conclude that while the reduction in lake levels due to the Chicago canal will have some effect on lake shipping interests, the effect will be very far from the wholesale destruction which has been pictured. Annual changes in lake levels due to natural causes are several times as great as any which the Drainage Canal can cause.

The part of Mr. Cooley's paper which seems to us of greatest interest and attention is his review of the methods by which it is feasible to control the level of all the lakes, and not only entirely remedy any lowering due to the Chicago canal, but to a large extent wipe out the present variation due to natural causes and hold the levels permanently at a point which will in effect add 2 ft. or more to the depths of every harbor and channel on the lakes. If the agitation aroused by the Drainage Canal work should finally result in works to control the level of the lakes and reduce their variations, the lake shipping interests would have good reason to bestow blessings instead of curses on Chicago and its work.

We alluded at the outset to the interesting legal questions which the Drainage Canal work has raised. The contention of the Board of Engineers that the United States has sole jurisdiction over it is doubtless correct, according to the latest Acts of Congress and court decisions. Would, then, the United States have a legal right to take charge of the canal on its completion, and wholly prevent its use for the purpose for which it was made? We hardly think that the law would justify so extreme a measure.

The general rule governing riparian rights is that any owner has the right to make such use as he pleases of the waters adjacent to his property, provided such use does not interfere with the rights of other owners or with navigation. Chicago has for years been taking from Lake Michigan nearly 1,000 cu. ft. of water per sec. and sending it over the divide to the Mississippi watershed via the Illinois & Mississippi Canal. She is now digging a new channel through which several times this amount will flow. Has she not the right to increase this flow up to the point where some deleterious effect upon lake levels becomes discernible. If all of Mr. Cooley's contentions are correct, a flow equal to the ultimate capacity of the canal will not produce an effect sufficient to enable the shipping interests to prove that an injury has been sustained. It is to be borne in mind, moreover, that a flow of only 5,000 cu. ft. per sec., instead of 10,000, is all that will be drawn from the lake when the canal is opened, and it seems pretty certain that this, at least, can be taken by Chicago without doing appreciable harm to any vested interest.

We may conclude, therefore, that even if the courts compel Chicago to turn over its canal on completion to the Government engineers, they can by no means prevent its use for the purpose for which it was designed. It would be a calamity, indeed, if, after expending $30,000,000 on this great work, the city were not allowed to make use of it; and no such outcome, we believe, need be feared.

The fact has been mentioned that the question at issue is International as well as National. In the above discussion, and in those given in preceding pages, the effect of changed lake levels on the depth of the St. Lawrence is not considered, but any satisfactory solution of the problem must certainly provide for the remedy of any injury which may be done to the Canadian canals. Should the reduced flow of the St. Lawrence, consequent upon the flow of the Drainage Canal, cause a reduction of 6 ins. in the depth of water on th miter sills of the St. Lawrence canal locks, Great Britain would have a just claim for reparation, according to international law.

The only satisfactory solution of the whole problem would seem to be for the United States and Canada to at once determine the feasibility of controlling the levels of all the Great Lakes and the waterways which issue from them; and unless unforeseen obstacles are found, to enter upon the execution of the work.

The control of the levels of these great freshwater seas, covering a hundred thousand square miles, would be indeed the most stupendous physical effect ever produced by man's agency, but from present appearances it could be carried out by methods entirely within the precedents of modern engineering, and at a cost quite inconsiderable in comparison with the benefits to be secured

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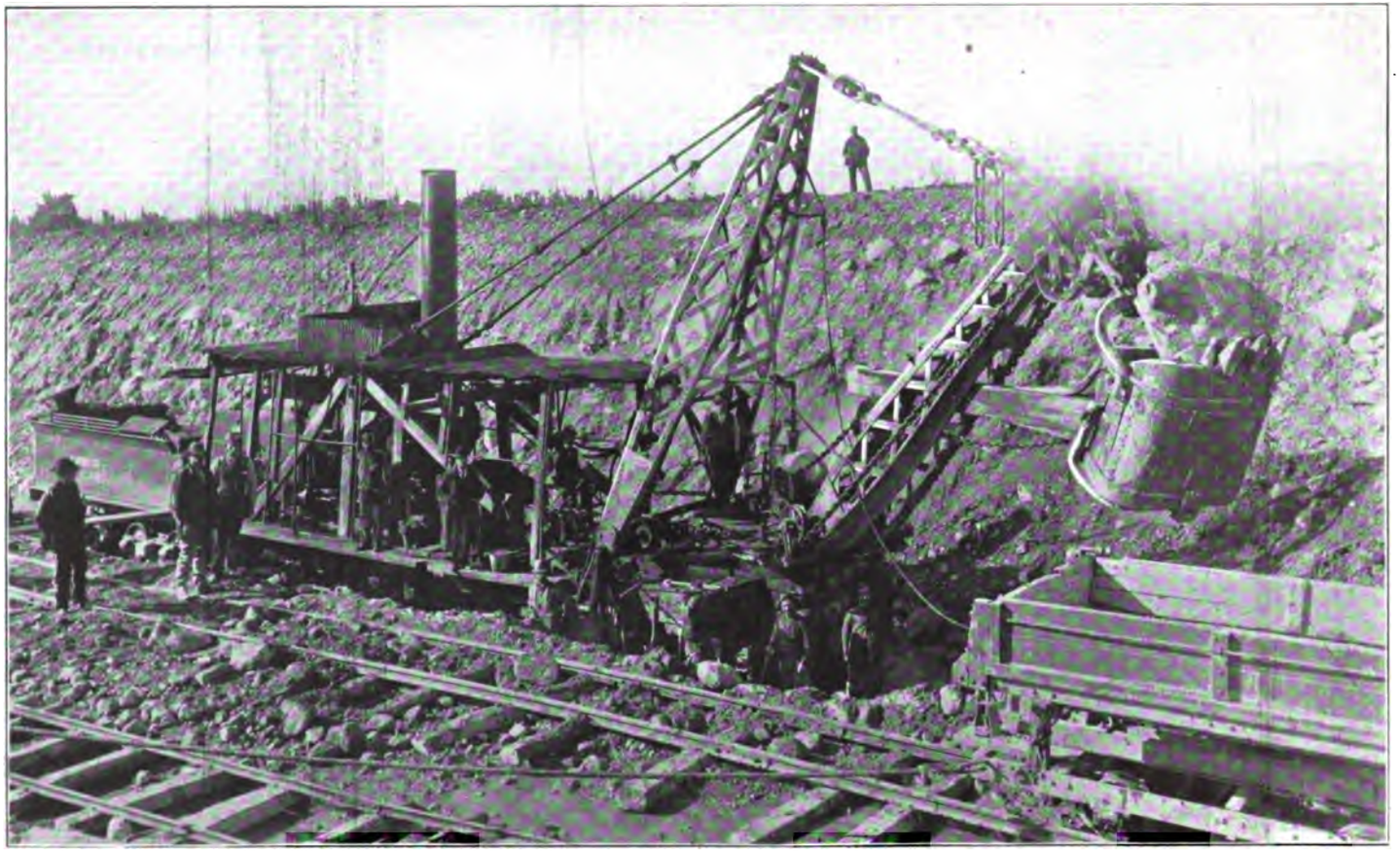

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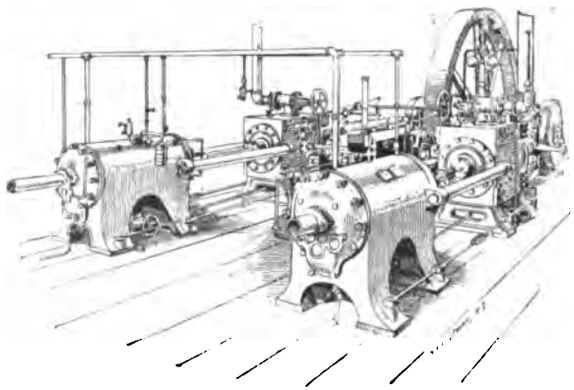

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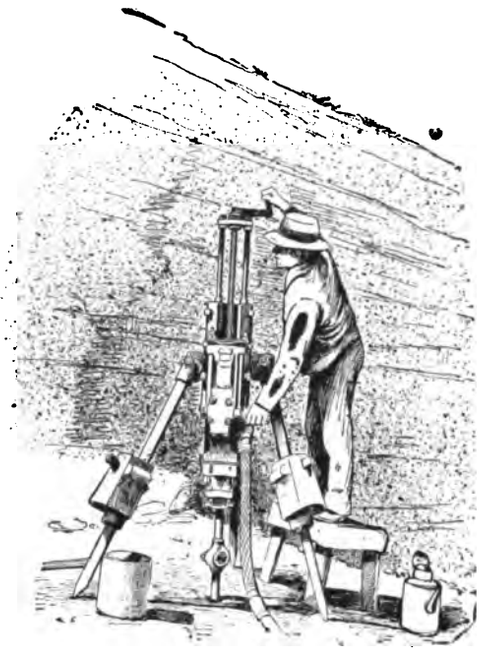

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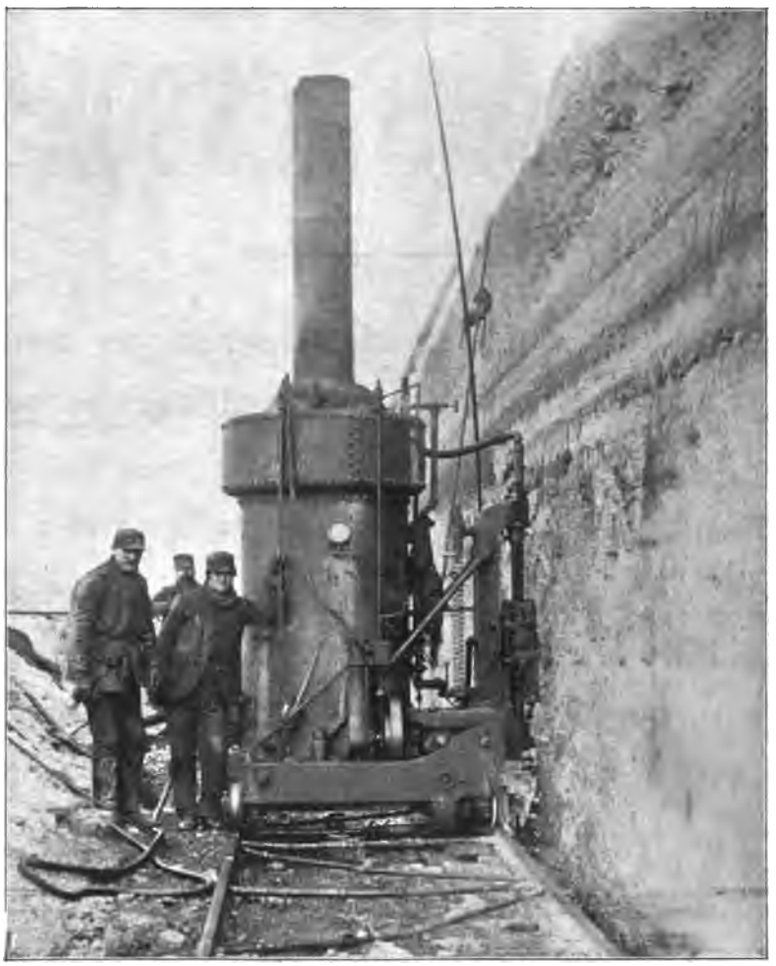

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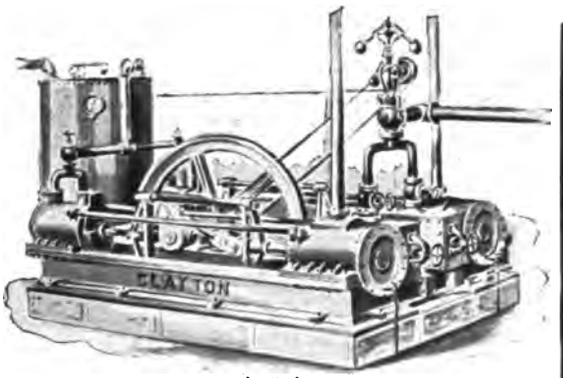

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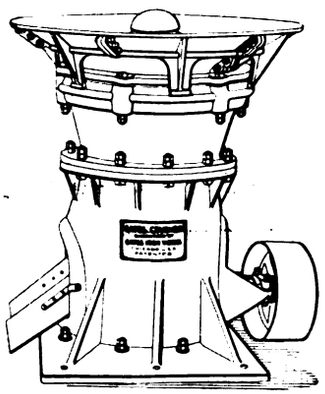
I have Steam Shovels, Hoisting Engines, Air Compressors, Channeling Machines, Rock Drills, Boilers, Pumps, Dump Cars, Scrapers, Wells Lights, etc., all in excellent condition. Most of it is nearly new. I can furnish promptly almost anything required in Contractors' Machinery.

In writing for particulars, kindly specify the articles you wish prices on.

WILLIS SHAW,

Office: 506 New York Life Building, - - CHICAGO, ILL.

GATES ROCK AND ORE BREAKER



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FOR DERRICKS, QUARRIES AND MINES.

Designs for Complete Crushing Plants.

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SELF-DUMPING and SELF-RIGHTING HOISTING BUCKETS

for Handling Coal, Ores, Clay, Sand, Etc.

Side, End and Bottom Dumping Cars; Iron Wheelbarrows, Hoisting Blocks, Etc.

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DIAPHRAGM PUMPS

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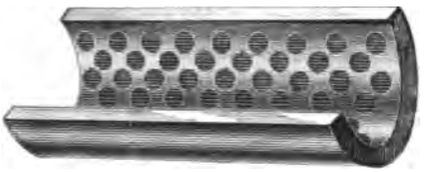

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Our Patented **Adjustable 5-Roller** Bushings are ahead of all others.

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Muddy or gritty liquids handled without injury to the Pump.

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CABLEWAYS Hoisting and Conveying Devices

PATENTS OF

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MULLINEX,
LOCKE,
DELANEY
and others.

Send for Catalogue and further particulars.

20 LIDGERWOOD TRAVELING CABLEWAYS
Sold and in use on the Chicago Main Drainage Canal.

OUR DEVICES

Are especially adapted for Canal and Trench Excavation, Dam and Bridge Construction, and are also extensively used for Mining, Quarrying, Logging, General Railroad and Contract Work, Pile Driving, Dock Work, Loading and Discharging Vessels, Cargoes, etc.

WE HAVE BUILT OVER 12,000 ENGINES

LIDGERWOOD ENGINES are built to gauge on the DUPLICATE PART SYSTEM, insuring absolute interchangeability of parts.

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ENGINEERS, DESIGNERS AND MANUFACTURERS OF

COMPLETE SYSTEMS FOR HANDLING OF MATERIALS.

THE BROWN PATENT { Bridge Tramway. Shed Tramway. Warehouse Tramway. Cable Tramway. Sewer Machine Tramway. Automatic Furnace Hoist.

The most perfect Machinery for Handling ORE, COAL, Etc., from Vessels, Docks and Cars. . . . . .

. . . SOLE MAKERS OF . . .

THE BROWN PATENT CANTILEVER CRANES in use on the Chicago Main Drainage Canal.

Working capacity of "Cantilever," 600 to 800 cubic yards "solid rock in place" per day of ten hours.

View showing "Cantilevers" taking rock from channel, and transferring same to spoil bank. Length of Cantilever over all, 853 feet. Maximum height of spoil bank, 80 feet.

ELECTRIC, STEAM and HAND POWER . . . . CRANES

The Best Machinery for Handling Materials in Shipbuilding Yards, such as Marine Plates, Armor Plates, Structural Work, Etc.

Designers and Builders of Traveling, Locomotive, Jib, Pillar and other Cranes; Friction Clutch Hoisting Engines; Boilers, Skip Cars, Self-Dumping Buckets, Friction Clutches, Etc.

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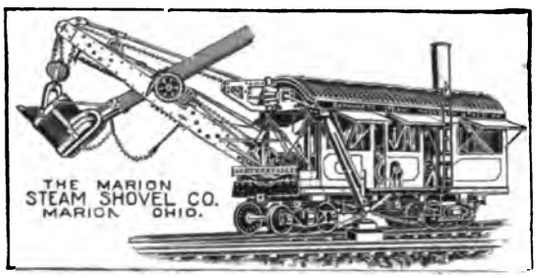
THE MARION STEAM SHOVEL COMPANY

Manufacturers of Steam Shovels, Ballast Unloaders, Dredges and Ditchers, suitable for all classes of work; also Inclines and Special Machinery for Mining.



A LARGE number of the contractors on the Chicago Drainage Canal were equipped with our machinery, among these were The Western Dredging & Improvement Co.; Christie & Lowe; Weir, McKechney & Co.; Gahan & Byrne; Heldmaier & Neu; Angus & Gindele; The Qualey Construction Co, and others. Over twenty of our Steam Shovels were used on this work. The Patents of the Incline used by The Western Dredging & Improvement Company, and others on the Canal; are the property of this Company. To get an idea of what is thought of our machinery by its users, please read carefully the testimonial letters, which speak louder than anything we can say for its merits.

HELDMAIER & NEU, Contractors, Drainage Canal, Sec. A & B.
Main Office: Room 910, Security Bldg., Chicago. Office at Works: Mt. Forest, Ill.

THE MARION STEAM SHOVEL CO., Marion, Ohio. Mount Forest, Ill., May 20, 1895.

GENTLEMEN: In reply to your favor of the 9th inst., we would say that we have sublet a portion of our work, and have a large quantity of the remainder excavated. We will not require another Shovel, but may conclude by saying that we sincerely repent not having purchased the Shovels we got from the Toledo Foundry & Machine Company from you; and if at any future time we may be in the market for these kind of machines, you will certainly get the order. We remain, yours respectfully, HELDMAIER & NEU.

OFFICE OF WEIR, McKECHNEY & CO., Drainage Canal.
Sanitary District, Drainage Canal, Sec. "F," Summit, Cook Co., Ill., Oct. 3, 1895.

THE MARION STEAM SHOVEL CO., Marion, Ohio.

GENTLEMEN: We have been using and are now using two of your Special Style AA Steam Shovels for the past six months, excavating glacial drift in the above-named sections. Every foot of the material has got to be blasted ahead of the shovel, sometimes breaking into very large lumps. The material is composed of an indurated clay, cemented gravel, hard pan and boulders—a material on which we believe that an ordinary Steam Shovel would not have lasted thirty days. We are happy to inform you that both shovels are giving entire satisfaction in every way; economy in renewal in repairs, which are simply normal. We have in our employ some steam shovel runners that were accustomed to the Bucyrus and other shovels, and they inform us that the No. 391 and 394 are the best shovels they ever had a foot on. They handle easy and quickly, and are standing the test now that they will never be called upon in this country or any country, so far as the material is concerned. We are working the shovels to a face of 25 feet. We should be pleased to have one of your representatives drop in and see us on your next visit to Chicago, and see what your machinery is doing. We cannot do it full justice on paper.

Yours very truly, WEIR, McKECHNEY & CO.

E. LEE HEIDENREICH, Prest. T. E. HILL, Supt. L. LEE HEIDENREICH, Sec'y and Treas.
THE HEIDENREICH CONSTRUCTION CO., General Contractors and Engineers,
539-543 The Rookery. Telephone, Main 5116 Cable Address: "Engineers, Chicago." (A. B. C. Code, 4th Edition.)
Specialties: Docking, Bridging, Pile Driving, Public Works, Railroads, Factories, Warehouses, Power Plants, Heavy Timber and Masonry Work.

THE MARION STEAM SHOVEL CO., Marion, Ohio. Chicago, Ill., January 11, 1896.

GENTLEMEN: In reply to your letter of recent date, in which you ask for a general expression of our experience with the Steam Shovels used by The Heidenreich Company on Sections L & M of the Chicago Drainage Canal, we would state that these shovels were put to work during the early part of 1894, and have handled since then up to last month about 1,700,000 yards of blue brick clay. We are pleased to inform you that the Shovels purchased from your Company have as a whole given us better satisfaction than those of other makes. Your Shovels are better adapted to make a close and economical slope cut; it makes a deeper cut, and if we had used your Shovels in cleaning and finishing up bottom of Canal, we would have saved quite a sum of money. Although not being in the market for any Shovels at the present time, we do not hesitate to say that we shall be pleased to recommend your make to anybody inquiring about same. Yours truly, S. L. HEIDENREICH, Secretary.

GEO. B. CHRISTIE. JESSE LOWE. GEO. A. LEDERLE.
CHRISTIE & LOWE, Civil Engineers and Contractors,
Room 512 N. Y. Life Insurance Bldg., No. 171 La Salle St. Telephone, Main 1092.

MARION STEAM SHOVEL CO., Marion, Ohio. Chicago, Ill., Feb. 20, 1896.

GENTLEMEN: Replying to your request for an opinion of the four Barnhart Style AA Steam Shovels purchased from you for excavating Secs. I & K of Chicago Drainage Canal, we are well satisfied with these machines, and can fully recommend them for similar work. These Shovels were given unusually severe service; they were operated continuously day and night for one and one-half years to completion of this contract, excavating a hard blue clay. A 2¼-yard dipper was used. On completion of this work the Shovels are in good condition.

Yours truly, CHRISTIE & LOWE.

THOMAS GAHAN. THOMAS BYRNE.
GAHAN & BYRNE, Contractors. Builders of Sewers, Water-Works, Macadam Roads, Drives and Boulevards. Water, gas and sewer pipes laid. Improving of subdivisions a specialty.
Telephone, Yards 635. Post Office Building, Cor. 12d and Halsted Streets.

MARION STEAM SHOVEL CO., Marion, Ohio. Chicago, Ill., Oct. 9, 1895.

GENTLEMEN: The two Special Style AA Barnhart Steam Shovels purchased from you in January, 1894, have been working continuously day and night since on Secs. G & H of the Main Drainage Channel of the Sanitary District of Chicago. Notwithstanding the hard nature of material excavated and the severe strain of constant usage, the Shovels have given entire satisfaction. Yours truly, GAHAN & BYRNE.

For Illustrated Catalogue and any other information desired regarding our machinery, address . . . . . .

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BUCYRUS STEAM SHOVEL & DREDGE CO.

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STEAM SHOVELS,
LAND DREDGES,
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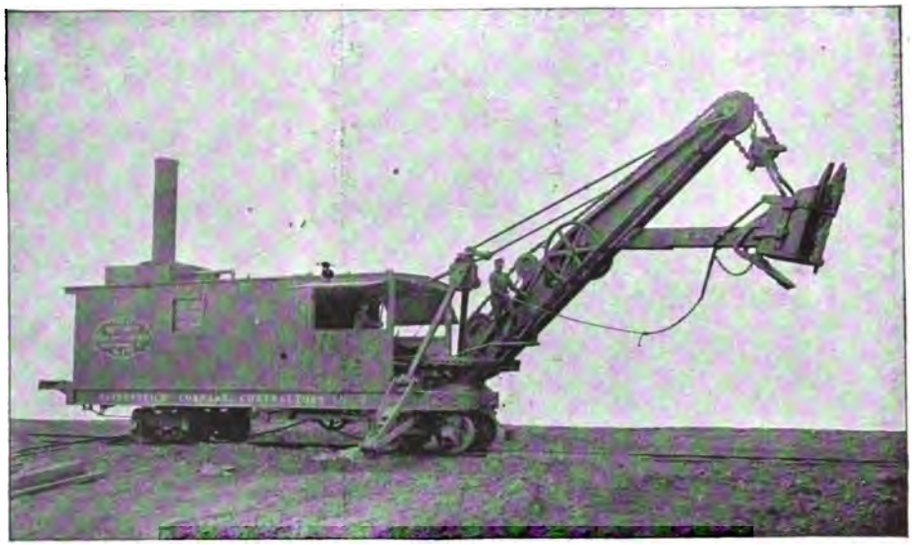
HOISTING ENGINES,
CENTRIFUGAL PUMPS.



Dipper Dredges,
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Placer Mining
Machinery.

50-TON STEAM SHOVEL, RAILROAD PATTERN.

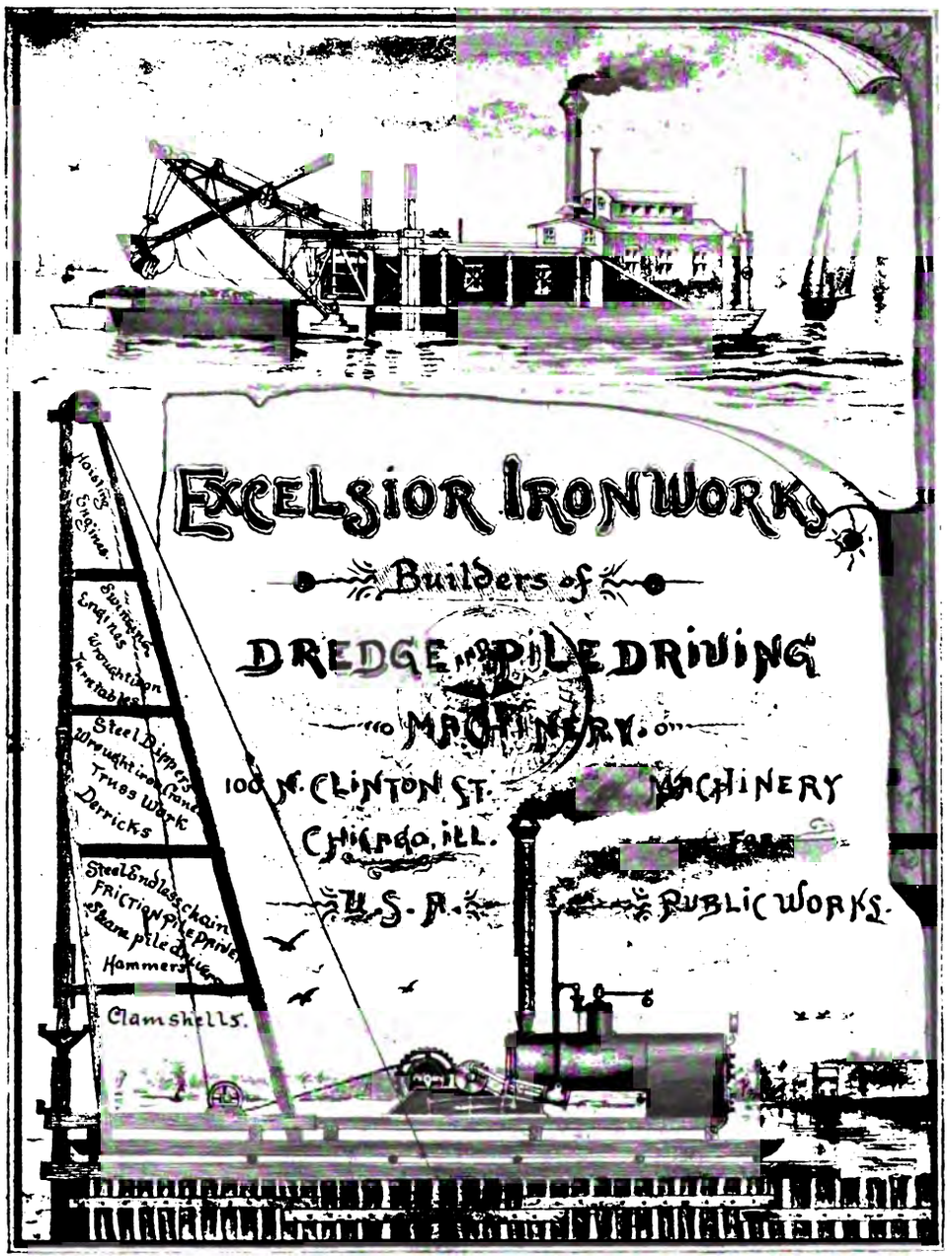
THIS Company furnished upwards of twenty-six steam shovels to the Chicago Drainage Canal, being more than all other makers combined. The hardest work on the canal was done by **Bucyrus** shovels. We have this year (1896) supplied seven powerful shovels to the Lake Superior Iron Ranges for working in iron ore, both for natural mining without blasting, and in frozen stock-pits. This proves conclusively that wherever it is necessary to have a powerful, durable and efficient machine for hard, continuous work, the **Bucyrus Shovel** is always adopted.

These are illustrations of our "Little Giant" Shovels at work on the Drainage Canal The last one is rock, as dumped.

We make Steam Shovels for all kinds of earth, ore or other excavation.

THE VULCAN IRON WORKS CO.,

CORRESPONDENCE SOLICITED. **TOLEDO, OHIO.**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Steam pile drivers
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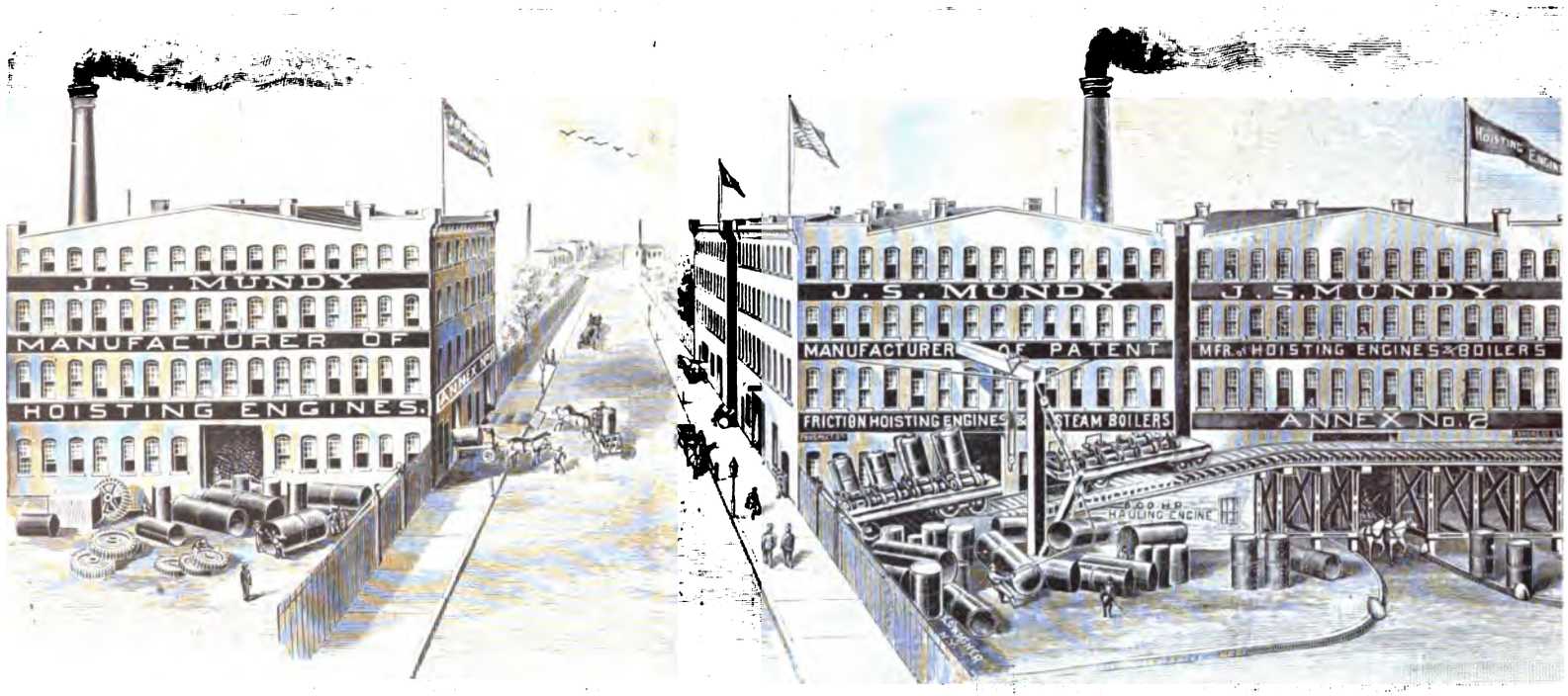
Clamshells.

MUNDY HOISTING ENGINE WORKS, NEWARK, N. J.

Established 1870. **19-23, 20-34 PROSPECT STREET.**



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Powerful Compound Geared Reverse Link Motion and Friction Geared QUARRY and Haulage Engines, WITH OR WITHOUT BOILERS, for **Hoisting, Mining, Bridge Erecting, Dock Building, Pile Driving, Coal Hoisting and Quarrying.** Of any power, with my improved Patent Friction Drums. Nineteen special large Mundy Engines were used in the construction of the Drainage Canal.

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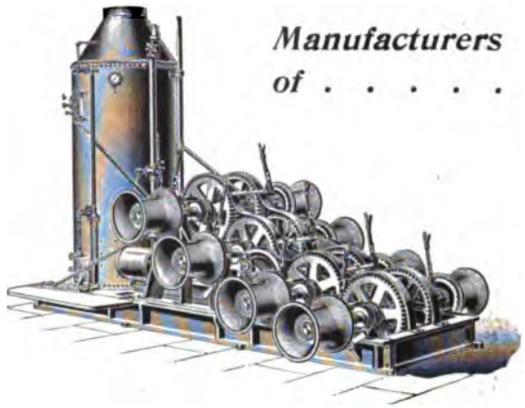
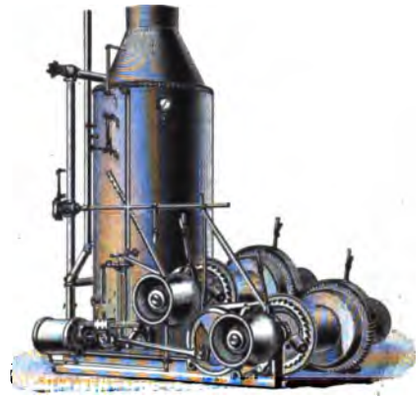
W. A. CROOK & BRO'S. CO., Newark, N. J.

SINGLE DRUM CONTRACTOR'S ENGINE.

Manufacturers of . . . . .



BRIDGE CONSTRUCTING ENGINE WITH EIGHT INDEPENDENT WINCHES.



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For Railroad and Bridge Building, Pile Driving, Excavating and Contractors.

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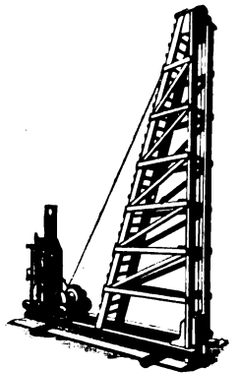
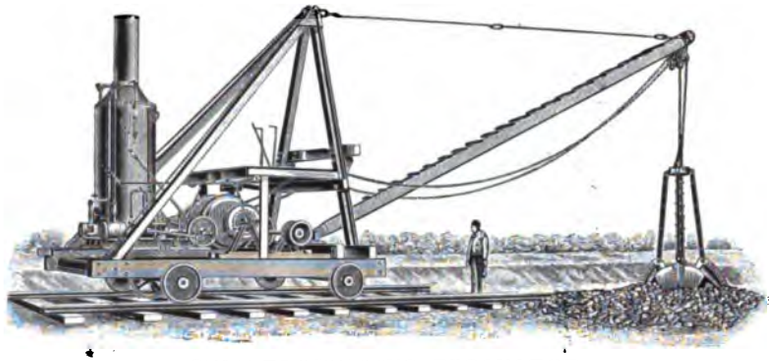


PILE DRIVER.



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WEBSTER, CAMP & LANE MACHINE CO.,

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High-Grade Hoisting Engines

AND

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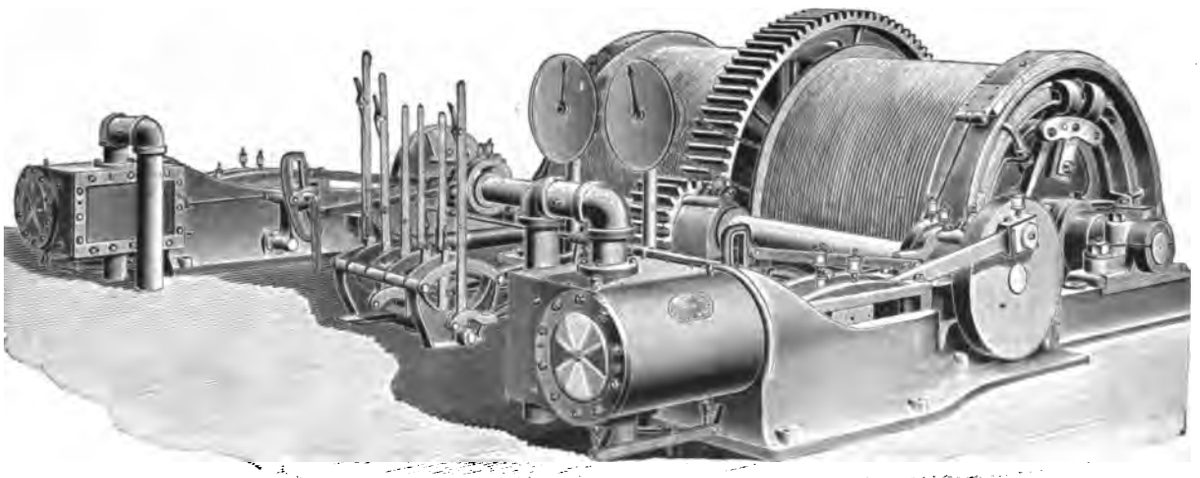

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Heavy Contractors' Engines and Boilers

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Made from special heavy patterns, designed especially for Mining and heavy duty.

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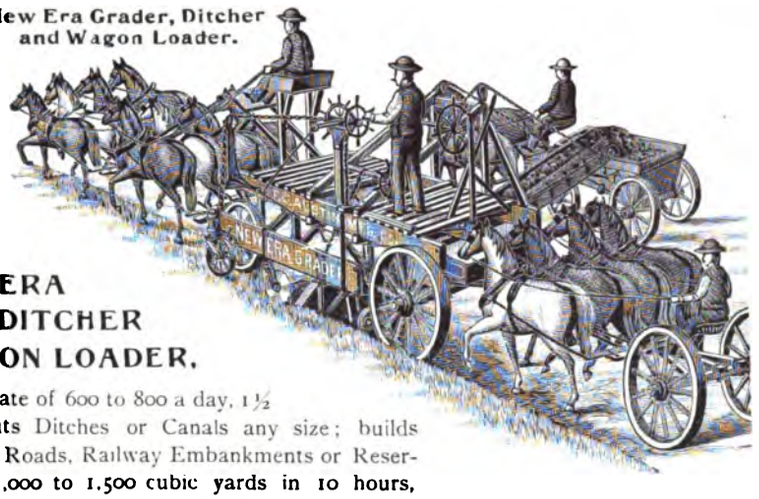

NEW ERA GRADER, DITCHER AND WAGON LOADER.

Loading at the rate of 600 to 800 a day, 1½ yards each. Cuts Ditches or Canals any size; builds Levees, Country Roads, Railway Embankments or Reservoirs, handling 1,000 to 1,500 cubic yards in 10 hours, with 6 teams and 3 men, at a cost of 1¼ to 1¾c. per yard.

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can be dumped without stopping the horses. Fitted for any running gear. Is strong and low-priced.

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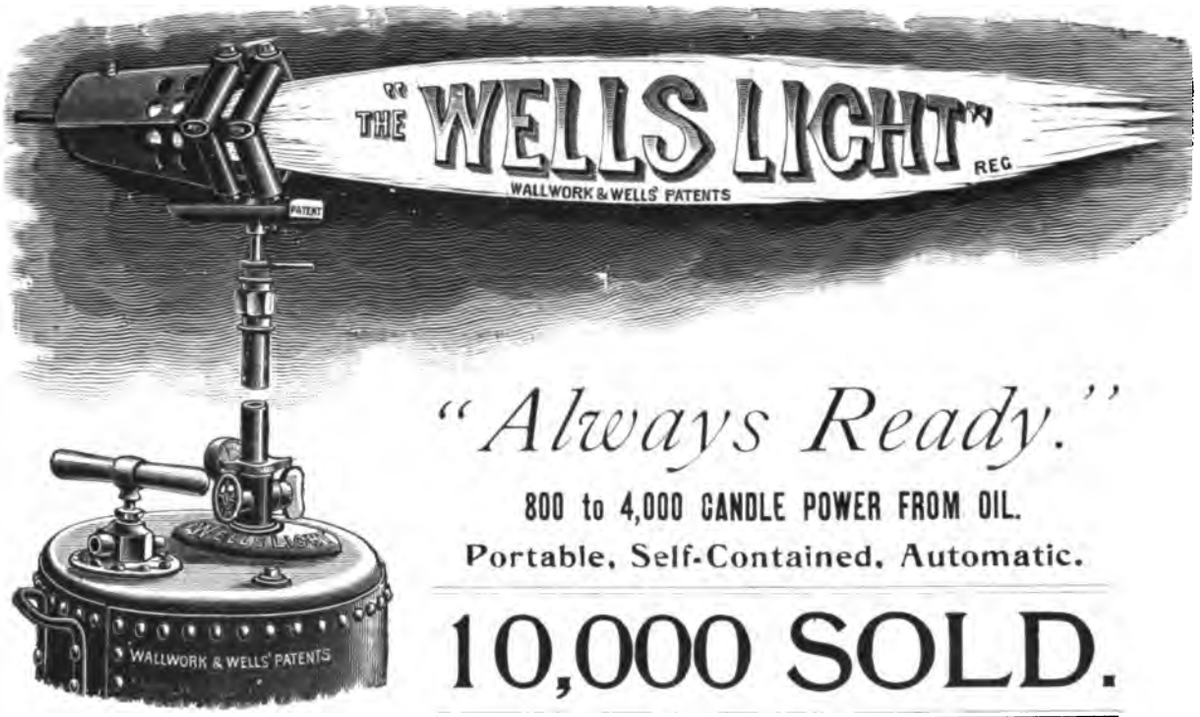

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